DOCUMENT RESUME

ED 127 194 SE 021 231

AUTHOR	Sohre, Beverly, Ed.
TITLE	What Are Things Made Of? MINNEMAST Coordinated Mathematics - Science Series, Unit 26.
INSTITUTION	Minnesota Univ., Minneapolis. Minnesota School Mathematics and Science Center.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	71
NOTE	247p.; For related documents, see SE021201-234; Photographs may not reproduce well
AVAILABLE FROM	MINNEMAST, Minnemath Center, 720 Washington Ave., S.E., Minneapolis, MN 55414
EDRS PRICE	MF-$0.83 HC-$12.71 Plus Postage.
DESCRIPTORS	Chemistry; *Curriculum Guides; Elementary Education; *Elementary School Mathematics; *Elementary School Science; Experimental Curriculum; *Interdisciplinary Approach; Learning Activities; Mathematics Education; *Physical Sciences; Primary Grades; Process Education; Science Education; Units of Study (Subject Fields)
IDENTIFIERS	*MINNEMAST; *Minnesota Mathematics and Science Teaching Project

ABSTRACT

This volume is the twenty-sixth in a series of 29 coordinated MINNEMAST units in mathematics and science for kindergarten and the primary grades. Intended for use by third-grade teachers, this unit guide provides a summary and overview of the unit, a list of materials needed, and descriptions of eight groups of lessons. The purposes and procedures for each activity are discussed. Examples of questions and discussion topics are given, and in several cases ditto masters, stories for reading aloud, and other instructional materials are included in the book. In this unit, chemical and physical properties of materials are examined. Properties studied are hardness, weight, volume, density, color separation, shape, solubility, and chemical reaction. (SD)

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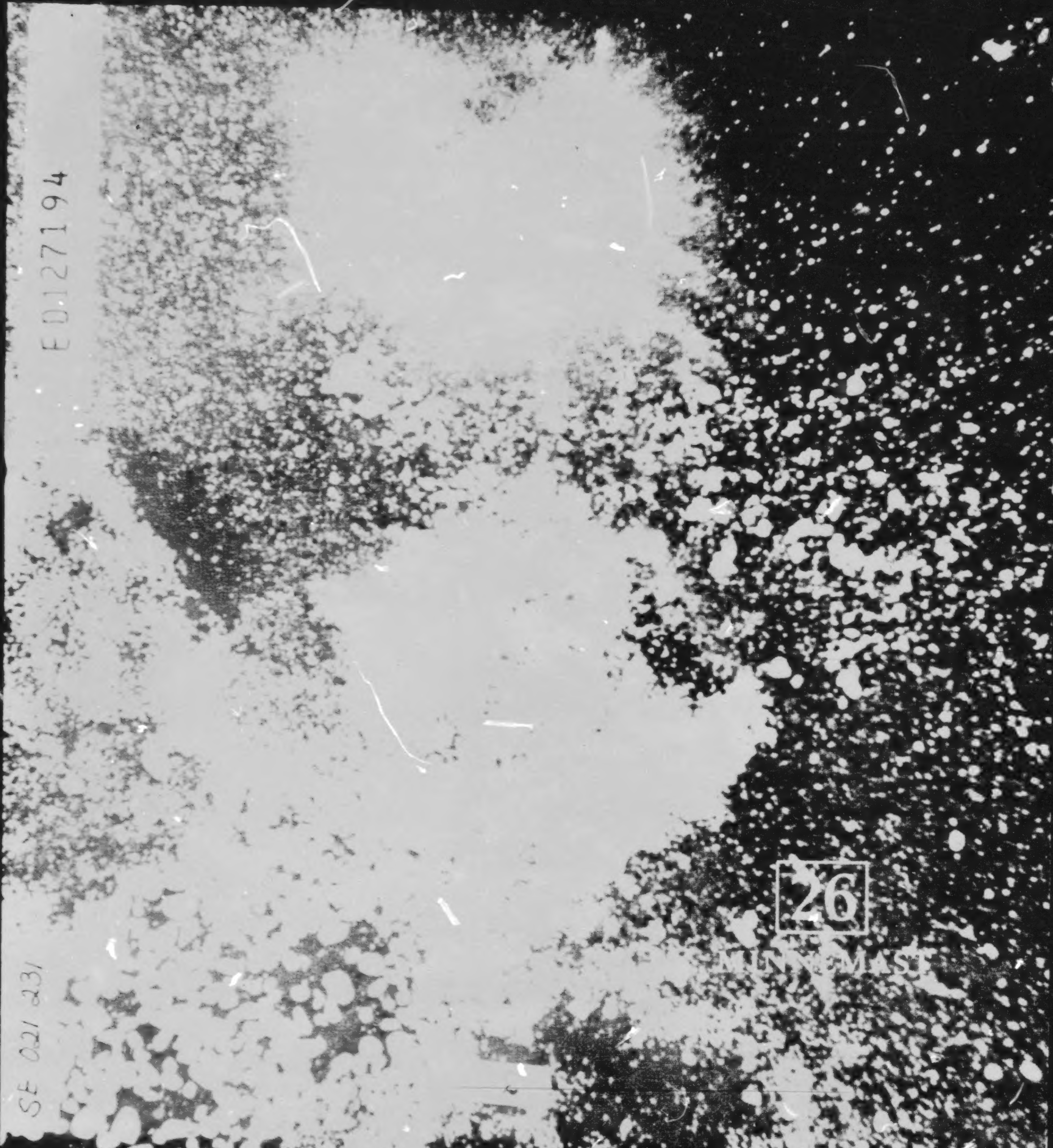
WHAT ARE THINGS MADE OF?



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26

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WHAT ARE THINGS MADE OF?

UNIT 26

MINNEMAST

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT
720 Washington Avenue S. E., Minneapolis, Minnesota 55455

MINNEMAST

DIRECTOR	JAMES H. WERNTZ, JR. Professor of Physics University of Minnesota
ASSOCIATE DIRECTOR FOR SCIENCE	ROGER S. JONES Associate Professor of Physics University of Minnesota
ASSOCIATE DIRECTOR FOR RESEARCH AND EVALUATION	WELLS HIVELY II Associate Professor of Psychology University of Minnesota

The Minnesota Mathematics and Science Teaching Project developed these materials under a grant from the National Science Foundation.

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Second Printing, 1971

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WHAT ARE THINGS MADE OF?

This unit was developed by MINNEMAST on the basis of the experiences of teachers who used an earlier trial version.

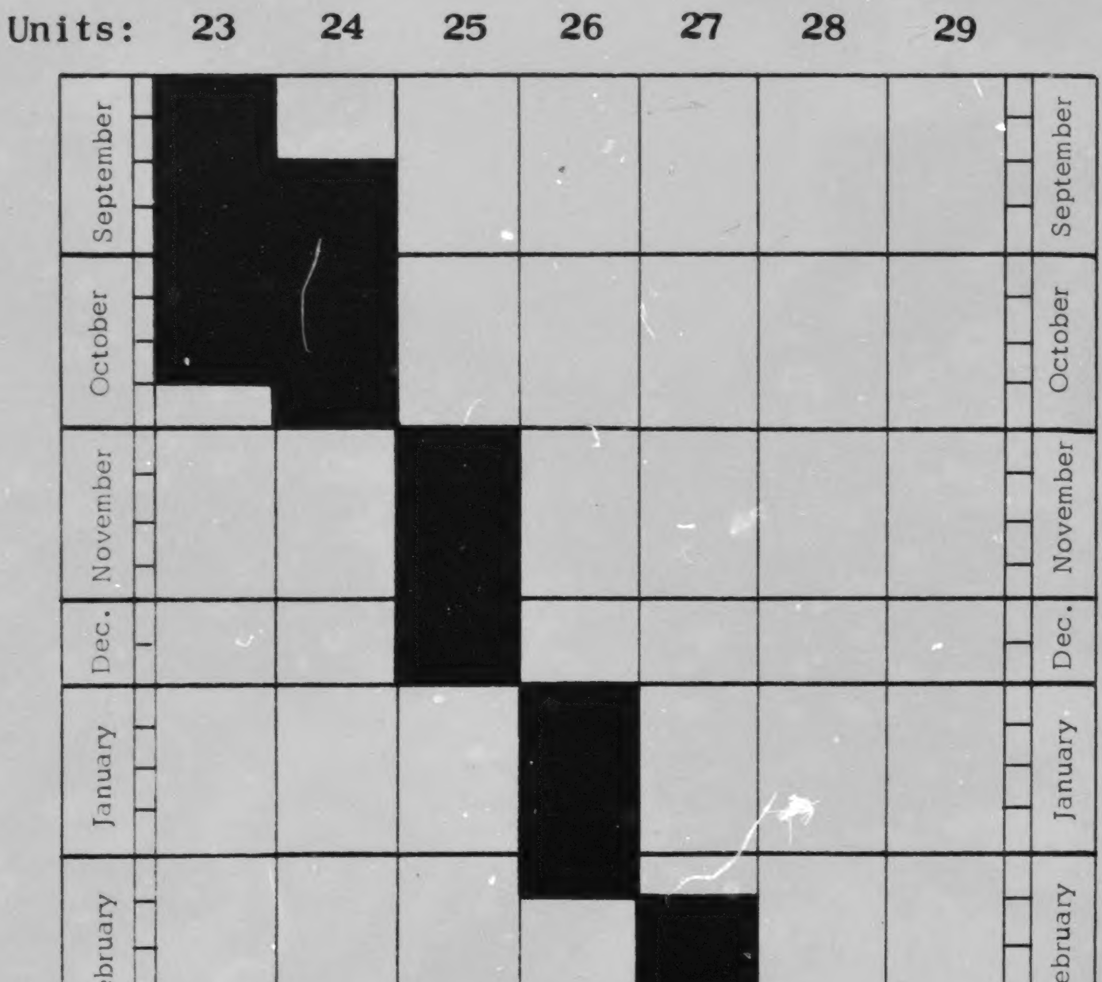
JEANNE BURSHEIM
Research Fellow
University of Minnesota

ALAN HUMPHREYS
Associate Professor of Elementary Education
University of Minnesota

WILLIAM B. SCHWABACHER
Professor of Chemistry
General College, University of Minnesota

ELAINE E. VOGT	Writer
BEVERLY SOHRE	Editor
JOHN WEISS	Technical Assistant
SONIA FORSETH	Art Director
JUDITH L. NORMAN	Illustrator

Suggested Teaching Schedule for MINNEMAST Third Grade Units



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Complete List of Materials for Unit 26

(Numbers based on class size of 30.)

total number required to teach unit	item	lessons in which item is used
30	** Student Manuals	
	broken discarded toys and other useless articles (children can bring these from home)	1
	tools such as files, pliers, screwdrivers and hammers (children can bring these from home or you can borrow from the custodian)	1
	pointed metal scissors	1
	old magazines or thick newspapers	1
1	* ball of string	1,4,5,6,8
30	* trays, paper, 14" x 18"	2,4,6,11,17
1 set	* metal sample kits	2,4,5,6,7, 8,12
4	* mineral sample kits	2,3,12,13, 14,16
5	* cartridges of Sheaffer washable black ink	2,11
5	* cartridges of Parker permanent blue-black ink	2,11
5	* cartridges of Parker permanent black ink	2,11
1	* package of Schilling food colorings	2,11
30	* souffle cups	2
1/4 lb.	sugar	2,12,17,18,19
1/4 lb.	* Epsom salt	2,12,19
1/4 lb.	table salt	2,12,17,18,19
1/4 lb.	* plaster of Paris	2,12,19
1/4 lb.	* cornstarch	2,12,18,19
1/4 lb.	* baking soda	2,12,18,19
30	* magnifiers	2,3,11,12,17, 18,20
1 or more	coarse-grained rocks, such as granite	3
30	scissors	3,10,13

8	pennies	3
8	* nails	3
8	* unglazed clay tiles	3
1	Mineralite Ultraviolet Lamp Set (optional)	3
1	* roll of cellophane tape	5,6,8,13
9 sets	* balance beam parts 5" x 5" x 5" cardboard triangles paper cups #1 paper clips	5
11	* plastic cylinders	6
11	* strips of centimeter tape	6
30	* medicine droppers	6,17,18
1 lb.	* clay	6,7,9
8	* measuring cups	6,19
2	* identical balloons	6
1	* grease pencil	6,16
1	* clear plastic container, at least pint size	6
1	sponge	6
36	straightened paper clips	7,9
30	* rulers	7,11
1	* cork	9
9	* penlight batteries	10
	several small objects to measure for density (children can bring these from home or they can be found in classroom -- see suggested list included in Lesson 10)	10
120	* white blotter strips	11
90	* 4-ounce plastic containers (32 with lids)	11,12,17,18, 20
5	* blue felt tip pens	11
5	* red felt tip pens	11
	any ball point, cartridge, or felt tip pens other than those previously used	11

1/4 lb.	*powdered chalk	12,19
1/4 lb.	*detergent	12,18,19
8	*plastic spoons	12
1	overhead projector	14
30	**protractors printed on transparencies	15,16
3	sheets of black construction paper	16
30	*sugar cubes	17
30	*1-ounce plastic containers (30 with lids)	17,19
1	*box of toothpicks	17,18,20
35	*4" x 4" squares of black construction paper	17
4	*plastic straws	17
32	*yellow Tinkertoy rods	17
30	*reaction trays	17,18,20
1	*pint of vinegar	18,20
4	*1-ounce bottles of phenolphthalein solution	19,20
1	*bottle of iodine	19,20
1	*roll of plastic wrap	19
1	raw potato	19
1	banana	19
	samples of materials, brought by children for testing (see suggested list at the end of Lesson 18)	19
1	knife	19
15	*styrofoam trays	20
1/4 lb.	*fine white sand	20

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* kit items as well as

** printed materials available from
Minnemath Center, 720 Washington Ave., S.E., Mpls., Minn. 55455

*** available from The Judy Company,
310 North Second Street, Minneapolis, Minnesota 55401

INTRODUCTION

Children who have been in the MINNEMAST program since kindergarten have had a great deal of experience in observing and describing the properties of objects. They have given verbal, qualitative descriptions of the properties, and frequently they have quantified their observations by measurements of such properties as length, area, volume and weight.

This unit brings in a new consideration -- the students will now focus on the properties of the material of which an object is composed rather than on the properties of the object itself. To introduce the idea, the children will first take apart useless objects brought from home. They will be able to identify a number of materials that are already familiar, such as cloth, glass, leather, rubber and wood. However, they will encounter other materials that they cannot identify with any degree of certainty. These doubts show the need for setting up tests that will help to distinguish one material from another.

The lessons are designed to teach some of the ways a material may be identified by its properties. The children will learn to test metals and minerals for the property of hardness. They will find out how to separate inks and food colorings into the component colors. The children will also learn to identify some minerals by the property of crystal shape and by the property of shape retention after cleavage. Finally, they will use solubility and chemical reaction as properties that a material may have.

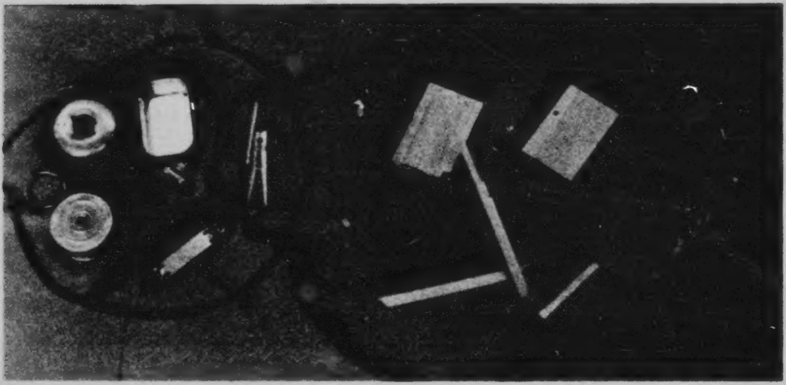
Science and mathematics are well coordinated in this unit. The mathematical concepts include intersection of sets, measurement of angles, and measurement and graphing of weight and volume. The children will particularly enjoy using their new transparent protractors to measure the angles on the models of crystal shapes they constructed.

The concluding lesson of the unit gives the children opportunities to use their experimental skills in identifying a variety of unknown white substances. They compare their new data from this activity with previous findings. Thus, the lesson also serves as a review and evaluation of what the children have learned.

As in the photograph above, children should always be gathered closely around the teacher for demonstrations and discussions of experimental procedure.

SECTION 1

PROPERTIES OF MATERIALS



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SECTION 1 INTRODUCING SOME PROPERTIES OF MATERIALS

PURPOSE

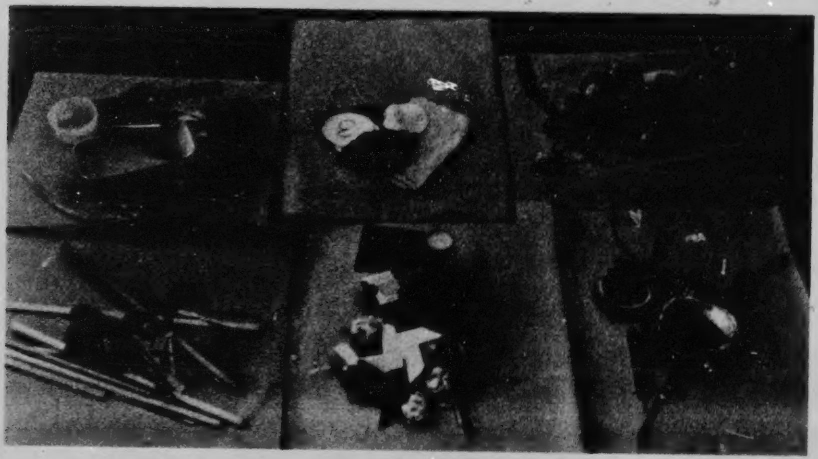
- To lead the children toward the idea that, although the properties of some materials are easily observed and identified, others may require special tests or techniques.
- To introduce a number of materials the children will investigate in other sections of the unit.

COMMENTARY

In Lesson 1 the children take apart a number of discarded, useless objects in order to sort the various parts according to the materials of which they are made. Eventually the children discover that some materials are not easily differentiated by observation, but may require special tests for correct identification.

In Lesson 2 the children are presented with a variety of materials that they will use later in the unit. Some of these materials cannot be identified easily or distinguished from one another. This motivates the children to learn some of the tests that scientists use to identify materials.

Teaching time for this section should be about two class periods.



Lesson 1: WHAT KIND OF MATERIAL?

Near the end of Unit 25, letters were sent home to the parents asking the children to bring discarded broken toys and other useless articles to school. The letters also requested the children to bring tools such as files, pliers, screwdrivers and hammers for use in this lesson. If the children have not brought these things, ask them to do so now. When you have collected one or two worthless objects per child, you are ready for the lesson. If the children have not brought enough tools, you may wish to borrow some from the school custodian.

In Activity A the children examine the materials in the collection of discarded articles and name as many materials as they recognize. Then two children are asked to make subsets from the set of all objects. One child makes a subset with objects containing wood. The other child makes a subset with objects containing metal. The class soon discovers that some of the objects belong in the intersection of the two subsets because these objects contain both metal and wood. The question then arises, "What can we do to the objects so that we will have only wooden material in one subset and only metal material in the other?" The answer, of course, is to break the objects apart.

In Activity B the children use the tools to separate the materials in the objects into subsets such as wood, metal, plastic, cloth, leather, glass, etc. Then, in show-and-tell fashion, they discuss the properties of each subset of materials. During these discussions you will have opportunities to ask the key questions, "How can we be sure this material really belongs in this subset? Doesn't it have the same apparent properties as this other material?" For example, when a child is describing the properties of a rigid, transparent, thin piece of plastic, you might ask him how he can be sure the material is plastic and not glass, since both seem to have the same properties. Such questions lead the children to realize that they need some scientific tests to discover differences in the properties of the materials in order to classify them correctly.

This lesson should be taught in a very informal manner so that the children enjoy the activities while at the same time they become interested in the properties of the materials. It is necessary to establish some ground rules for using the tools. Let the children help form these rules and discuss the necessity for them.

MATERIALS

- broken discarded toys and other useless articles (brought by the children)
- tools such as files, pliers, screwdrivers and hammers (brought by the children or borrowed from the school custodian)
- pointed metal scissors
- old magazines or thick newspapers to protect the floor from hammers
- 2 pieces of yarn or string, each about 10 feet long (optional)

PREPARATION

Label tools brought by the children so that they can be returned to the rightful owners at the end of the lesson.

PROCEDURE

Activity A

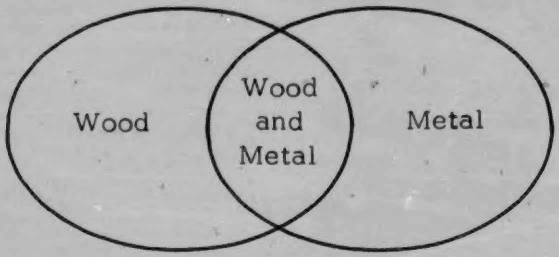
Clear a large area of the classroom floor. Bring out the collection of worthless objects and put them in a big pile at the center of the cleared area. Have the children gather around the pile. Explain that they are going to concentrate on the materials of which things are made, rather than on the objects themselves. Give the children a few minutes to examine and discuss the objects. Ask them to name some of the materials they recognize, such as cloth, plastic, glass, rubber, wood and metal. List these materials on the chalkboard.

Now ask the children to think of ways to sort the large pile of objects into subsets. The children may suggest such ideas as sorting by color or former use of the objects, etc. Let them discuss these possibilities without doing the sortings. If no child suggests sorting the objects by the kind of material in them, remind the class that the purpose of this unit is to investigate materials, not objects.

When a child does suggest sorting by material, assign one child to make a subset of objects containing wood. Ask another child to make a subset of objects containing metal. Have the rest of the class observe the sorting closely. The children should raise their hands if they disagree with the placement of any object. Sooner or later the problem of placing an object that contains both wood and metal should arise. When it does, ask:

> WHERE SHOULD WE PLACE THIS OBJECT THAT CONTAINS BOTH WOOD AND METAL? SHOULD WE PLACE IT IN THE WOOD SUBSET OR IN THE METAL SUBSET?

Let the children speculate and make suggestions. Eventually they should see that the object belongs in both subsets. One way of showing this is to use two pieces of yarn to form Venn diagrams like the following, on the floor:



Explain to the children that objects containing more than one material would always have to be placed in the intersection of subsets. Ask them to look at the pile of objects and notice that many of the objects would belong in intersections of various subsets. Then say:

> WHAT COULD WE DO TO THESE OBJECTS SO THAT WE COULD HAVE ALL WOOD IN ONE SUBSET AND ALL METAL IN ANOTHER?

The children will see that to eliminate the intersection of subsets they will have to take the objects apart, which is what they will do in the next activity.

Activity B

Remove the yarn from the floor and push the metal and wood objects back into the original pile. Bring out the tools and ask the children to help you make up some rules for their use. They should help you establish a few simple safety precautions, such as these:

1. The files are pointed and should be handled carefully to avoid injuring a child, the furniture or the floor.

2. A buffer, such as magazines or thick newspaper, is necessary under objects being pounded with a hammer so that the floor will not be damaged.

3. Glass should not be broken with hammers or with any other tools. It should be separated from the other materials in an object only if this can be done easily with the hands. Children who are working with glass should be closely supervised.

When the children understand the rules, divide the class into groups of four or five and assign one material to each group. You may wish to use the materials previously listed on the chalkboard. Instruct the children to take one object at a time from the pile, remove the material they are looking for, and then return the remainder to the pile so the others can take materials from it.

Let the children work with the tools until most of the objects in the pile have been separated and the materials classified into subsets. Collect the tools.

Ask each group to select a spokesman to describe the properties of the group's material. During these descriptions, challenge the sortings with questions that will cause the children to realize that sometimes observation alone does not reveal enough properties for correct classification. Lead the children to see the need for tests to discover hidden properties of some materials. For example, if a child is describing the properties of his group's material (e.g. plastic) as "hard, easy to see through, and thin," ask:

> HOW CAN YOU BE SURE THAT THIS MATERIAL IS NOT GLASS?

If another piece of plastic looks like rubber, ask the children in the group about that. Some plastics also look and feel very much like wood or leather -- how can the children be sure which material it really is?

NOTE: In discussing the subsets your questions should bring out the need for better identification of some materials. Lead the children to the idea that they could discover more properties of a material and learn to distinguish one kind of material from another if they knew more ways of testing materials. Encourage them to think about ways of testing for properties in these materials.

When the discussions are ended, dispose of the materials in any way you wish. The children may want to take many of the battered objects home. If they do not, have the custodian dispose of them. At this time, send home the borrowed tools. Tell the children that in the next lesson they will get a preview of some of the materials they will use in this unit.

Lesson 2: PREVIEWING AND SORTING MATERIALS

This lesson introduces many of the materials that will be used in the unit. Each group of four or five children receives a tray of materials to sort into subsets. The materials for the different groups need not be identical, but should include a few each of the minerals, metals, liquids and white substances listed below. The groups should decide for themselves by which properties they will sort the sets of materials into subsets. The children in one group might decide, for example, to sort the materials into liquid and non-liquid subsets. Then they might wish to divide the non-liquid subset into more subsets according to the properties of color or hardness. Encourage the children to use their senses of sight and touch to identify each kind of material. Ask them to be careful when smelling the various materials, because a deep inhalation of some substances could be dangerous. Do not permit the children to taste any of the materials at any time. Let them refer to the minerals as "rocks" in this lesson -- they will learn the distinction in the next lesson.

After the children have separated the materials into subsets such as metals, rocks, colored liquids, white powders, etc., they try to determine whether or not the materials in each subset are all of exactly the same kind. Since they cannot be sure, reemphasize the point made in Activity B of Lesson 1 by asking, "What could we do to find out more about the properties of these materials, so that we could tell one kind from another?" The children should see that they need specific tests that will help them differentiate among the materials.

MATERIALS

-- for each group of four or five --

- tray
- a few pieces of metal
- a few mineral samples
- several liquids such as the ink cartidges and food colorings

- several soufflé cups each containing a substance such as sugar, Epsom salt, table salt, plaster of Paris, cornstarch, baking soda, baking powder, or any white substance of similar appearance
- magnifier

PREPARATION

Place the materials for the groups on trays. All of the items you will need for this lesson are provided in the third grade kit. To these you may wish to add other easily-obtained white substances such as flour, cream of tartar, scouring powder, etc. For the purposes of this lesson, it is not necessary to open the food colorings, nor the ink cartridges. Hide the tops of the boxes the minerals came in.

PROCEDURE

Activity A

Divide the class into groups of four or five children and provide each group with a tray of materials. Tell the children you want them to spend some time examining the materials with their eyes and with their hands. Encourage them to use the magnifiers. Explain the danger of sniffing things too closely, and emphasize especially that they must not taste any of the materials.

Ask each group to divide its set of materials into subsets by any properties they choose. If the children seem to have trouble getting started, remind them of some of the properties with which they are already acquainted, such as color, wetness, hardness, weight, size, etc. Go about the room as the children work. In cases where groups have made very simple subsets such as liquid and non-liquid, suggest that the children try to sort each subset again by another property. When all groups have completed this work, call on the children of each group to explain what they have done.

WHICH PROPERTY DID YOU USE TO SORT YOUR SET OF MATERIALS INTO YOUR FIRST SUBSETS?

WHICH PROPERTY DID YOU USE TO SORT YOUR FIRST SUBSETS INTO STILL MORE SUBSETS?

Let the class examine and question the subsets of each group. Encourage such questions as, "Why is this material in this subset?" and "Which of your senses did you use to observe this property?"

Select one subset of white powders and ask the children in the group whether they think all the powders are of the same material. They may answer that some powders seem to have finer particles or feel softer than others, but they can't be sure about identifying the powder. Ask whether they can notice any differences in properties.

Next ask one group if the objects in their metal subset are all made of the same material. If children try to identify the metals, focus their attention on the properties.

Go through this procedure with a subset of inks and of food colors.

Activity B

Ask the children in each group to examine their set of rocks.

ARE ALL THESE ROCKS MADE OF THE SAME MATERIAL? HOW COULD WE FIND OUT?

Have the children discuss with you ways they might identify the rocks. They may suggest that this could be done by studying the colors and shapes of the rocks. Then ask whether they think two rocks could be of the same color or shape, but not of the same material. The children may then suggest comparing such properties as weight or texture. These are good suggestions. Use them to lead the children to see that perhaps, if they had new ways of testing the materials, they could find out more about the properties of each, and that this would help identification.

Tell them that in the next few weeks they will learn about several tests they can use to tell more about the properties of these materials. They will be learning some of the tests that scientists use to distinguish between one material and another. Say that eventually they will be able, by testing, to distinguish between each of the metals, the powders, the inks, and the rocks. In the next lesson they will be concentrating on the "rocks."

Collect the materials. Discard the powders and store the liquids and metals. Keep the minerals on hand for use in the next lesson.

SECTION 2

PROPERTY OF HARDNESS

SECTION 2 THE PROPERTY OF HARDNESS

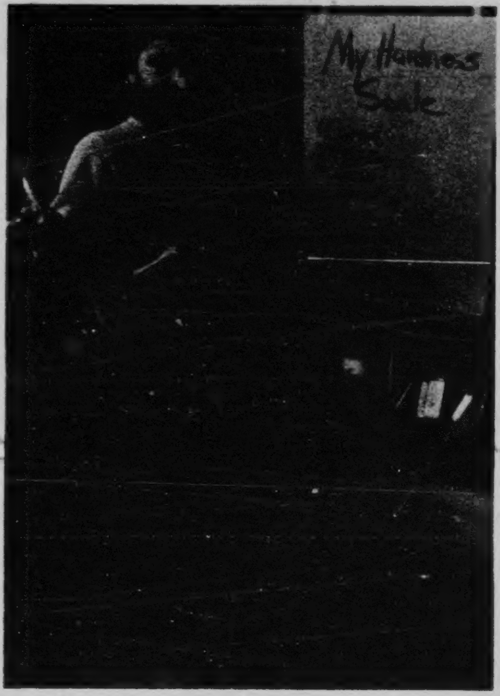
PURPOSE

- To present a method for testing the hardness of materials.
- To acquaint the children with a standard scale of hardness used in mineral identification.

COMMENTARY

This section will focus attention on the property of hardness. Although children have an intuitive understanding of the property of hardness, the idea of using different hardnesses in a scale will be new to them. The activities include the development of a technique for comparing the hardness of two objects, the ordering of minerals based on the property of hardness, and the introduction of a standard scale of hardness (Mohs' scale). The children will become aware that hardness is a valid test in the identification of minerals. Later in Section 6, "The Property of Shape," they will become familiar with another property used in mineral identification -- that of crystal shape.

This section consists of two lessons. Teaching time should be from two to three class periods.



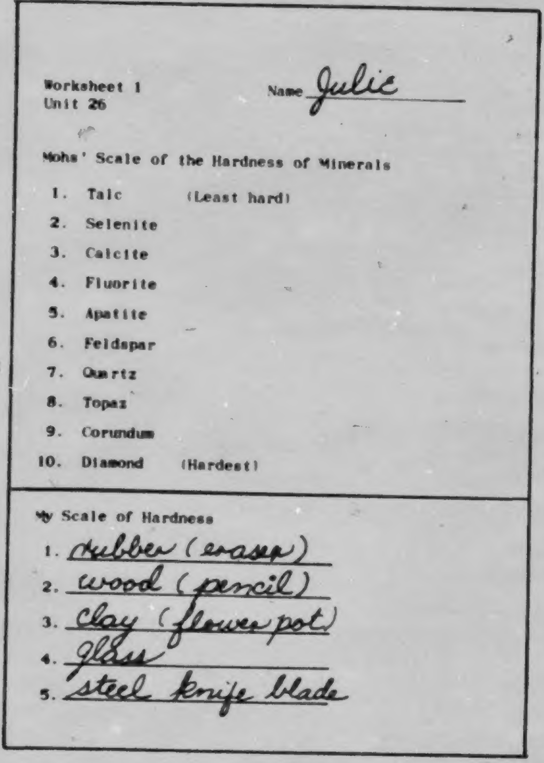
Lesson 3: THE HARDNESS OF MINERALS

In this lesson the children first learn the difference between minerals and most rocks. Then they investigate five mineral samples and discover that some are harder than others. By scratching one mineral with another, they can determine which of the two is the harder. (The one that is scratched is always the softer.) The children are then given a penny, a soft iron nail and a clay tile to arrange in order of hardness with their mineral samples. They also determine the relative hardness of the metal in the scissors.

When the groups have completed their orderings, the entire class participates in ordering by hardness all nine of the minerals provided in one of the kit sets. They compare this ordering with Mohs' scale (given below) and identify each of the minerals. (The only mineral sample not provided in the kits is # 10, the diamond.)

An optional activity follows the identification of the minerals. The children may, if they wish, make a hardness scale of their own at home, using various materials they find there.

Another optional activity shows a different property of some minerals -- fluorescence. The beauty of fluorescent minerals is very interesting and exciting to the children, but you would need to borrow or buy a Mineralite Ultra Violet Lamp Set to give the demonstration. (Some schools have these sets or some child may have one.)



Worksheet 1
Unit 26

Name Julie

Mohs' Scale of the Hardness of Minerals

1. Talc (Least hard)
2. Selenite
3. Calcite
4. Fluorite
5. Apatite
6. Feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond (Hardest)

My Scale of Hardness

1. rubber (eraser)
2. wood (pencil)
3. clay (flower pot)
4. glass
5. steel knife blade

MATERIALS

-- for the class (Activity A) --

- 1 or more coarse-grained rocks such as granite, in which more than one mineral is visible
- 1 or more magnifiers

-- for each of eight groups (Activity A) --

- magnifier
- metal scissors of the type normally used in the third grade
- mineral samples numbered 1, 4, 6, 8 and 9 (to be removed from the mineral set and jumbled together)
- 1 penny, 1 soft iron nail and 1 unglazed clay tile

-- for the class (Activity B) --

- 1 set of nine minerals (with numerals removed)
- Mohs' scale in Student Manuals

-- for Optional Activity D --

- 1 Mineralite Ultraviolet Lamp Set and fluorescent minerals (Borrow from junior high, or from one of the children.)
- fluorite samples from the mineral sets (These fluoresce.)
- minerals that do not fluoresce (also from the sets)
- fabrics in the clothing the children are wearing

PREPARATION

Most of the materials you will need for the required activities of this lesson are provided in the third grade kit. There are enough materials so that you can divide the class into eight groups of children. In addition, you will need eight pairs of scissors, eight pennies and one or two coarse-grained rocks. You may wish to ask a child to bring in the rocks.

Select from each box of mineral sets the following: numbers 1, 4, 6, 8 and 9. Have the magnifiers, scissors, iron nails and clay tiles handy. Put the boxes containing the rest of the materials away for use in Activity B. Hide the covers, too, because Mohs' scale is printed inside each box cover and this would reveal the order of hardness (as well as the identity of each mineral) before the children have had an opportunity to do their own testing.

Use only one full set of minerals with numbers removed in Activity B. This will leave seven sets of the crystal-type minerals unscratched and in good condition for use in Section 6, in which the children study crystals.

PROCEDURE

Activity A

Show a coarse-grained rock to the class. Ask if the rock seems to be made entirely of the same material. Select a child to observe the rock closely. Give this child a magnifier to help him see that the rock is composed of many small particles. Then pass around the rock and magnifier (and other similar rocks if you have them) so that the children can see the different particles.

Now give each group a magnifier and a set of the five mineral samples you have set aside for them. Have the children examine these stones with their magnifiers. Ask how these stones are different from the rock they observed previously. Explain that some of the stones they are now observing are similar to the different kinds of particles they saw in the rock. Say that each of the five stones they now have contains only one kind of material. Then give this definition:

> WHEN A STONE IS MADE UP OF ONLY ONE MATERIAL, WE CALL IT A "MINERAL." WHEN A STONE IS MADE UP OF MORE THAN ONE KIND OF MATERIAL, WE USUALLY CALL IT A "ROCK."

Ask the children to inspect all of their mineral samples and to tell you if they think all the samples are alike. (No, they are not.)

CAN ANYONE THINK OF A WAY WE COULD TEST THE MINERALS TO FIND OUT WHETHER OR NOT THEY ARE MADE OF DIFFERENT MATERIALS?

If the children do not think of the scratch test to determine the hardness of each mineral, ask them to discuss a property that all of the minerals have -- hardness. Suggest that if some of the minerals are harder than others, the harder ones should scratch the softer ones.

Provide scissors and ask the children to divide their sets of minerals into two subsets: (1) those the scissors can scratch and (2) those the scissors cannot scratch.

Next add to each group's materials a penny, a soft iron nail and a clay tile. Tell the children you want them to test all of these things (including their mineral samples) for hardness and to arrange them in order with the softest at their left and the hardest at their right. Ask them to test the hardness of the scissors and to include the scissors in the ordering, too.

If necessary, show the children how to do the scratching. For example, when testing the scissors, they will need to try to scratch along one of the open blades. But, when testing something else with the scissors, they will use the point of the blade.

NOTE: The children should all be shown how to tell which of two minerals has really been scratched. This can be done by removing all of the powder from each sample and finding the one that has been scratched. The one with the scratch is the softer of the two. If both samples are scratched, they are of about equal hardness.

When all the groups have finished the ordering, go about and check the results. The ideal result would be:

Mineral # 1 (least hard) (at extreme left)
Penny
Mineral # 4
Soft iron nail
Scissors
Mineral # 6

Mineral # 8
Clay tile
Mineral # 9 (hardest) (at extreme right)

However, mineral samples may be imperfect and scissors may differ in hardness. Then, too, some children may not be able to scratch hard enough to determine where to place the scissors or the harder minerals. Have other children from groups with good results lend their minerals and skills to groups with poor results until all the children have participated in a more satisfactory (if not perfect) ordering.

Then ask the children to test their fingernails for hardness, using the materials at hand. (Everyone should be able to scratch mineral #1, but some may be able to scratch the penny also.)

Collect all the materials and put the mineral samples back in the boxes.

Activity B

Tell the children that a geologist (a scientist who studies rocks and minerals) uses hardness as a basic property by which to identify minerals. Also say that the geologist uses a scale similar to the ordering the children have just done, and -- in fact -- the five mineral samples they examined in Activity A are in the scientist's scale.

Remove the numerals from one complete set of nine minerals and place the minerals on a demonstration table. Have the children gather around. Call on different children to scratch one mineral with another until all nine have been ordered correctly. Distribute the Student Manuals and tell the children that, of the minerals listed in Mohs' Scale of Hardness on Worksheet 1, the only one missing from their set is the diamond. Ask them to identify their minerals using the scale on the worksheet. You might like to explain that Friedrich Mohs was a German geologist who developed this hardness scale for minerals over a hundred years ago.

Ask a few children to compare the hardness of their fingernails, a penny, scissors and a clay tile with the minerals to find their position in relation to Mohs' Scale.

Activity C (Optional)

Let the children tear the page with Mohs' scale on it from their Student Manuals to take home. Suggest that they test various discarded materials at home to make up their own hardness scales. Remind the children not to scratch furniture or other valuable household items, but to look for aluminum or steel cans, rocks, broken pieces of pottery, old pieces of wood, etc. If a child wishes to bring his materials and his scale to school, provide him with the demonstration set of minerals used in Activity B and let him see where his materials would fit in the mineral scale. Some may be softer than talc, and so would precede it, whereas others might fit between two numbers. No material is likely to be harder than the corundum (#9).

Activity D (Optional)

If you have access to an ultraviolet lamp and some fluorescent minerals, by all means use them. The lamp, even when turned on, looks black -- but do not let the children gaze directly into it at any time. Put the fluorite samples from the mineral sets under the lamp to show how they fluoresce. Then put some of the other minerals under the lamp to show that they do not fluoresce. After handling fluorescent minerals, the children may discover that spots on their hands or clothing will fluoresce under the lamp. Even without the presence of traces of the minerals, certain colors in their clothing will also fluoresce. Point out that testing for fluorescence with an ultraviolet lamp is one more way scientists find another property by which to identify some minerals.

If you have a cultured (or natural) pearl, it will fluoresce blue under the ultraviolet lamp. Pearls are composed principally of calcium carbonate, which the children can see in another form in their mineral samples of calcite. The pearl fluoresces, not because of its calcite content, but because of the presence of small amounts of other minerals.

The children may be interested in knowing that their teeth and bones, as well as those of animals, are made of the same mineral as their samples of apatite. Doctors of Veterinary Medicine can detect one of the common diseases of cattle if the teeth fluoresce red.

Lesson 4: HARDNESS AND OTHER PROPERTIES OF METALS

The main purpose of this lesson is to have the children focus on the weight and size properties of some metal materials as a preliminary step in their understanding of density, a property they will soon be studying. Other purposes are to show the children that in some cases it is necessary to test more than one property in order to identify a material, and to show the need for accurate methods of measuring weight and size (volume).

The children observe a number of metal samples and try to determine whether all are composed of the same material. By using the scratch test, they find out that some of the metals are harder than others. This leads to the hypothesis that perhaps these metals are not all composed of the same material. To test the hypothesis, the children compare the weight of different samples by hefting. They discover that some of the pieces seem heavier for their size than others. In other cases, they cannot be sure whether there is any weight difference between two samples at all. They also discover that, except for two cubes, they have no reliable way of measuring the size of the metal pieces. These two discoveries point up the need for quantitative measurements of weight and size (volume). In Lesson 5 the children will measure the weight of the metal pieces and in Lesson 6 they will measure the volume.

MATERIALS

Metal pieces from the OMSI kit, labeled as follows:

- 2 "O" pieces from plastic container marked "Unknowns"
- 2 "W" " " " " " "
- 2 "S" " " " " " "
- 2 "T" " " " " " "
- 2 "C" pieces from container marked "Aluminum"

- 2 "H" pieces from container marked "Aluminum"
- 2 "E" pieces from container marked "Pr. Type"
- 2 trays

PREPARATION

On the two trays, put one sample of each of the metals listed above. Place the trays on a demonstration table.

PROCEDURE

Have the class gather around the demonstration table. Pass one tray of metal samples around to half of the class and the other tray to the other half. As the children examine the metals, ask them to describe some of the properties they observe. (They may describe the pieces as hard, silvery, dull, heavy, light, large, small and shiny. Some children will notice that the metals are marked and that some are slotted with round holes and others with rectangular holes.) You may want to list some of the properties on the chalkboard.

When, after five or ten minutes, all the children have had an opportunity to handle the metal pieces, ask if they think all of the metal pieces are composed of the same material. Let the children speculate. Then ask:

> HOW CAN WE FIND OUT IF ALL THESE METAL PIECES ARE MADE OF THE SAME MATERIAL OR OF DIFFERENT MATERIALS? (By testing some of their properties.)

Probably the most obvious test for the children to suggest at this time is the scratch test for hardness. If they don't, suggest it yourself. Have the children from each half of the class test their set of metal pieces for the property of hardness. Record their findings on the chalkboard. The order should be this:

Least Hard	Next Hardest	Hardest
Object E	Objects T, O, H, C	Objects S, W

Remind the children that if two materials can scratch each other, they are of approximately the same hardness. Therefore S and W belong in the same subset and T, O, H and C belong together in another subset.

From the results of this hardness test, the children will want to conclude that the metal pieces are made of three different kinds of material and that some of them are made of the same material. Point out that this is a rather broad statement to make from a test of just one property, and that perhaps they should use the statement as a hypothesis to be tested further. Mention that scientists sometimes find it necessary to make tests of many properties before they can identify a material. Then ask the children to think of some other properties they might test and compare.

If the children mention the property of size, let them try to order each set of metal pieces according to that property. (It will be very unsatisfactory, except in the case of the two cubes.) Use this fact to point out the need for some better way of measuring size.

Next give metal pieces C and E to a child. Ask him to place one piece in each hand and compare them for the property of weight. Have several children do this. Results may vary. One child may say they seem to weigh about the same; another may say that maybe E weighs a little more, even though it is smaller in size.

Now have metal pieces O and W compared by several children, asking them to heft the pieces and tell what they think. (W is much smaller in size than O, yet it is hard to tell by hefting which piece weighs more.)

Finally, have several children compare pieces S and T, the two metal cubes.

> WHAT DO YOU NOTICE ABOUT THE SIZE AND WEIGHT OF OBJECTS S AND T? (They are both the same size, but S weighs more than T.)

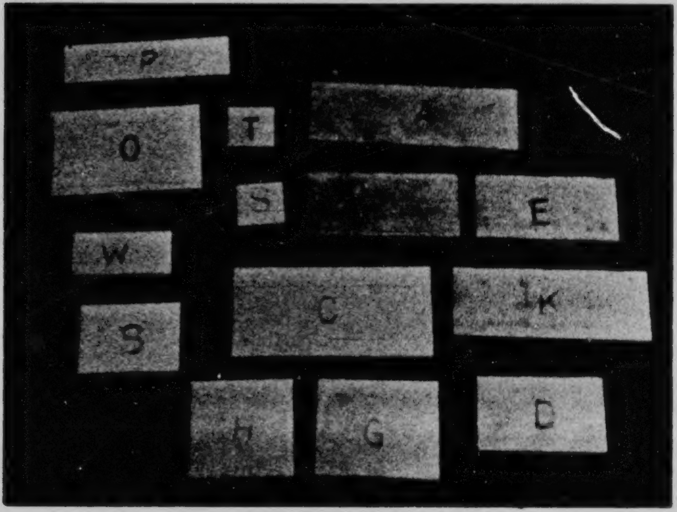
Give all the children an opportunity to heft S and T, and see if the class can come up with any statement that indicates a little intuitive knowledge of the relationship between size and weight. Do not mention the word, "density." A perfectly satisfactory generalization at this point is:

> SOME MATERIALS SEEM TO WEIGH MORE FOR THEIR SIZE THAN OTHERS.

Ask the children if they can tell you how much more one object weighs than another. Also ask if they can tell you how much larger one object is than another. Use their answers to show the need for methods of measuring both weight and size. Have the class think about ways they might measure weight. Some children may remember using the beam balances in previous work. Say that in the next lesson they will construct and use beam balances to measure the weight of metals. After that they will have to find some way of measuring the size. Suggest that they think about such a method, and ask:

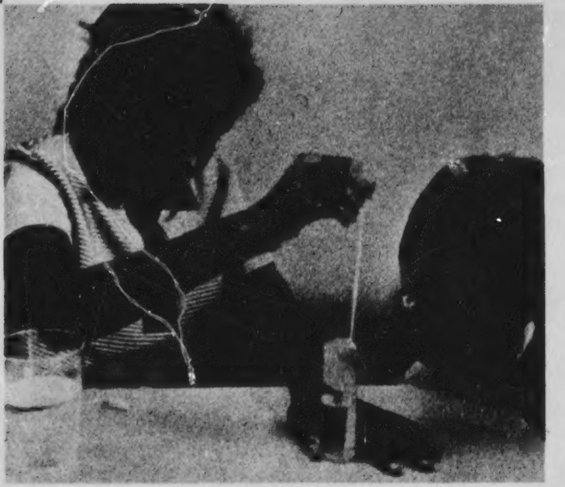
> IF WE COULD MEASURE THE WEIGHT AND THE SIZE OF EACH PIECE OF METAL, WOULD IT HELP US TO IDENTIFY EACH ONE? (Maybe not, but at least we would know about three properties of each rather than just one.)

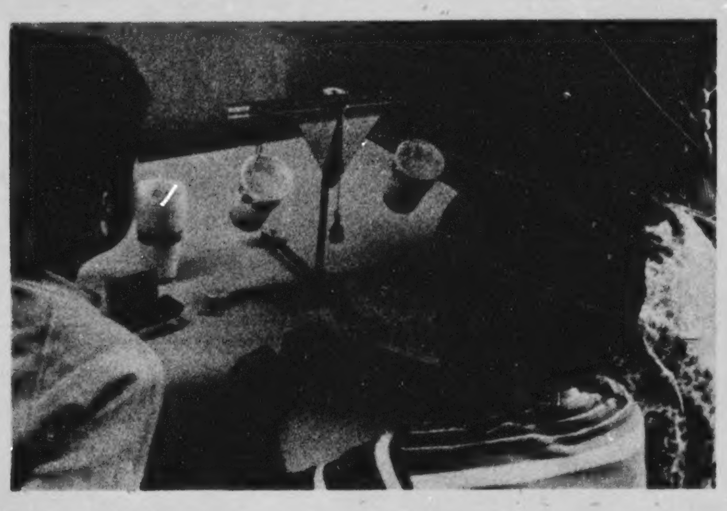
The same samples will be used in the next lesson.



SECTION 3

WEIGHT AND VOLUME





SECTION 3 THE PROPERTIES OF WEIGHT AND VOLUME

PURPOSE

- To give the children experience in measuring weight and volume in preparation for their work with density.
- To initiate the idea that, for a given material, there is a relation between volume and weight.

COMMENTARY

The property of density is the relation between two other properties of a given material, namely between the material's volume and its weight.

To study density with any degree of understanding, the children must study and see the relation between the properties of weight and volume. The two lessons of this section are designed to give the children this preliminary experience.

In Lesson 5 the children construct beam balances with which to measure the weight of the metal objects they have been studying for the property of hardness. In Lesson 6 they use calibrated cylinders with water to measure the volume of the same metal objects. The children record the data on worksheets for use in the next section of the unit.

The techniques for weighing and for measuring volume by water displacement should be familiar to the children from work in previous units. They should be able to assemble the beam balances rather quickly, but if they cannot, remember that it is time well spent -- the beam balances will be used extensively in five lessons. They can be left assembled and ready in a convenient storage area, to be brought out when needed. Similarly, the volume measuring equipment should be kept handy for use throughout the next section.

In these lessons, the children should learn to measure both weight and volume very carefully, and to record the measurements carefully, too.

Teaching time for this section should be about two class periods.

Lesson 5: MEASURING THE WEIGHT OF METALS

In Lesson 4, the children noticed a difference between the weight and the size of the metal objects, particularly between objects S and T. They said, "Some objects seem to weigh more for their size than others," but they had no way of quantifying either property. They decided they needed some way to measure the weight and the size of each object in order to see what relationship there was. In this lesson they learn to measure (quantify) the weight of each metal. In Lesson 6, they will learn how to measure each object's size. Then in Lesson 7, they will have data about both weight and size, and can draw some conclusions about the density of different kinds of materials.

To reemphasize the need for accurate measurements, the children again try hefting objects O and W in their hands. Then short strings are attached to these objects and the children heft them by letting them dangle from the strings. Results from the two methods of hefting are usually contradictory. Even if they are not and the children become quite adept at deciding which of two objects is the heavier, they still have no way to determine how much heavier one is than another. This short activity leads to the introduction of the beam balance.

The children construct and use beam balances to measure the weights of the seven pieces of metal they used in the last lesson. Worksheets 2 through 5 show how the beam balances are assembled. Children who have studied MINNEMAST Units 16 and 22 have already constructed and used beam balances. Therefore, a minimum amount of time should be spent here in constructing the balances and in reviewing how to use them. Each child should record the weight (in paper clips) of each metal on Worksheet 6 and save it for use in later lessons.

MATERIALS

-- for the class --

- metal objects C, E, H, O, S, T and W

- 4 pieces of string, each about 5 inches long
- tape
- 1 preassembled beam balance (Make it like children's.)

-- for each group of four --

- one 5" x 5" x 5" cardboard triangle
- paper or plastic bag containing Tinkertoys and other materials with which to construct a beam balance (See PREPARATION.)
- 13 extra paper cups to use as units of weight (Two others are used in the construction of the balance.)
- 10 small (#1) paper clips to use as lighter units of weight (One paper cup is nearly equivalent in weight to 10 of these paper clips.)

-- for each child --

- Worksheets 2 through 6 in the Student Manuals

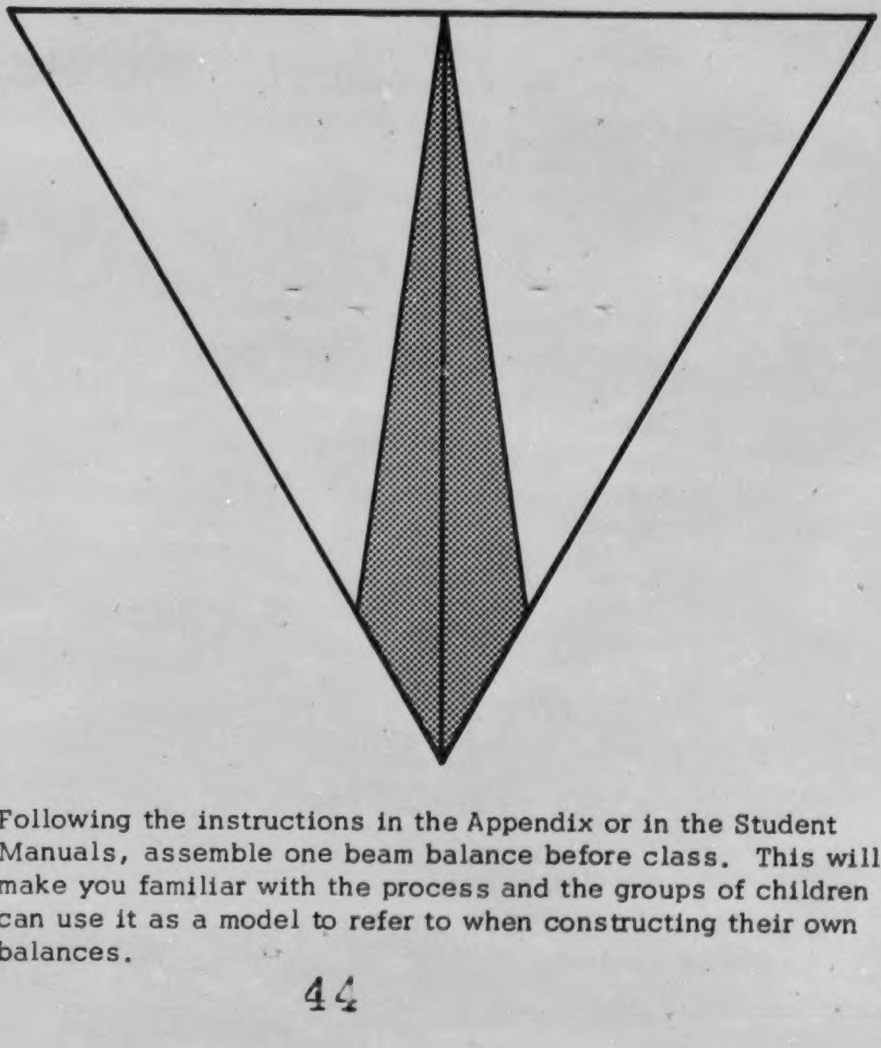
PREPARATION

Ask a few children to help you go through the OMSI kit and find the materials necessary for the beam balances. Have them put the following items in a bag for each group of four children:

1 blue Tinkertoy rod
3 red Tinkertoy rods
1 purple Tinkertoy rod
6 round Tinkertoy joints
1 ruler perforated with round holes
1 picture hook
2 Jumbo paper clips
2 paper cups
1 lead sinker (bob)
1 twelve-inch piece of string

Also ask your helpers to count a stack of 13 paper cups for each group and to put ten #1 paper clips in the top cup. You may also wish to let the children help you cut and prepare the cardboard triangles for the front of the balances. To do this you need scissors, a ball point pen, a ruler and a red crayon.

From cardboard, cut one 5" x 5" x 5" triangle for each group. Choose any side of the triangle as the top, and draw a straight line from the center of the top straight through the center of the angle at the bottom. Use a pen for this. From the bottom point, measure up one inch along each side. Draw pen lines from each of these points to the top center of the triangle. With red crayon, color the area between these two lines. Your helpers may now put one of these triangles in each group's bag.



Following the instructions in the Appendix or in the Student Manuals, assemble one beam balance before class. This will make you familiar with the process and the groups of children can use it as a model to refer to when constructing their own balances.

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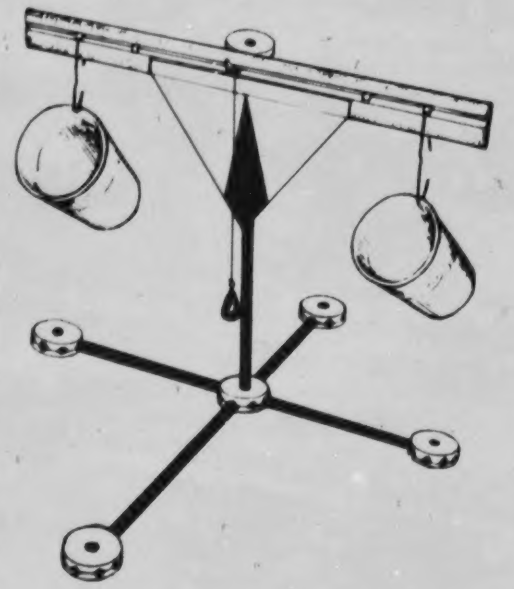
Worksheet 2
Unit 26

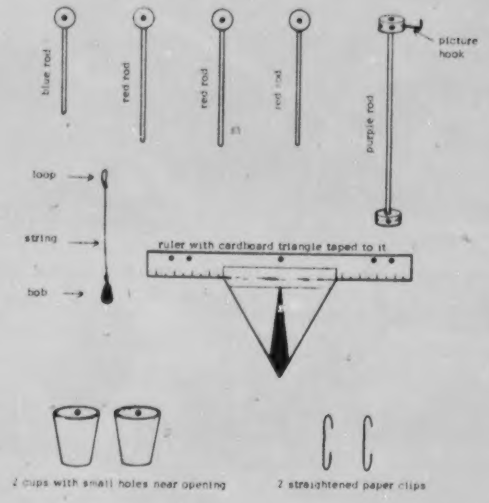


Completely Assembled Beam Balance

Worksheet 3
Unit 26

PARTS FOR BUILDING A BEAM BALANCE

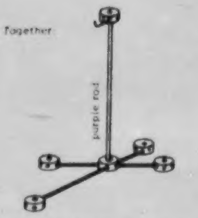
Kit Items:


blue rod
red rod
red rod
red rod
picture hook
purple rod
loop
string
bob
ruler with cardboard triangle taped to it
2 cups with small holes near opening
2 straightened paper clips

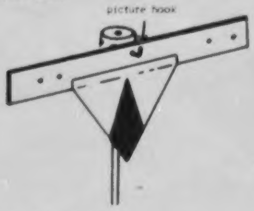
Worksheet 4
Unit 26

Steps in Putting Beam Balance Together:

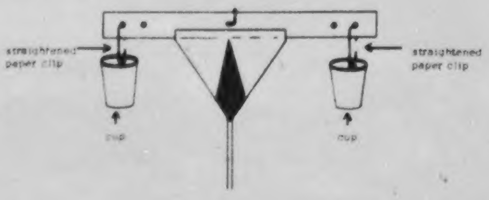
Step 1. Put stand together.



Step 2. Put balance arm on stand by slipping the center hole of the ruler over the picture hook.

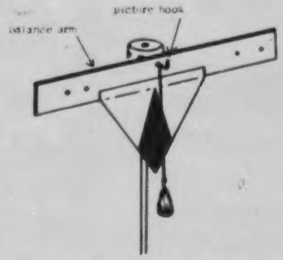

picture hook

Step 3. Attach two cups to the balance arm.

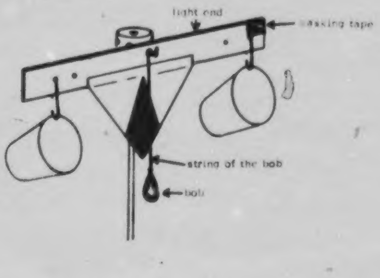

straightened paper clip
straightened paper clip
cup
cup

Worksheet 5
Unit 26

Step 4. Attach bob to the end of the picture hook. (Caution: Make sure the balance arm does not touch the string of the bob.)


picture hook
balance arm

Step 5. Adjust the balance arm by putting masking tape on the end which is too light. When the beam is balanced, the bob string should be lined up with the center line of the red triangle.


light end
masking tape
string of the bob
bob

PROCEDURE

Activity A

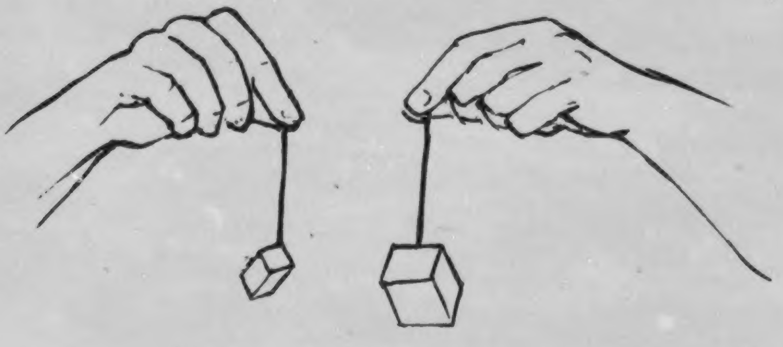
Have on hand the two O and the two W pieces of metal, four short strings and some tape. Have the children gather around a demonstration table. Briefly review the main point of the last lesson -- that there seemed to be some sort of relation between the weight of a piece of metal and its size, but that to find out what the connection is, they need ways to measure and compare the weight and size of each object. Tell the children that in this lesson they are going to measure only weight, not size. Ask:

> HOW CAN WE MEASURE THE WEIGHT OF THESE METAL PIECES? WAS HEFTING A GOOD METHOD?

The children should remember that hefting the pieces in their hands was not a very accurate method of measuring or comparing weights. Nevertheless, pass around objects O and W and ask each child to decide which piece is heavier, by hefting. Have them do this quickly and keep a score on the board. (Most of the children will probably say that W is heavier.) Then say:

> LET'S TRY ANOTHER METHOD OF HEFTING. MAYBE THIS WILL WORK BETTER.

With tape, fasten one 5-inch string to an end of each of the two O and the two W pieces, leaving about 4 inches of string dangling. Have the children heft an O and a W by holding the ends of the string.



Ask each child which piece of metal felt heavier this time, and keep score. (Most of the children will probably say that O felt heavier this time.) Whatever the results, some children will have changed from W as the heavier to O as the heavier. From this contradiction of their previous judgment, the children should see even more clearly than before that hefting is not a reliable method of comparing weights, especially when there is not much of a weight difference.

> WHO CAN SUGGEST A WAY WE COULD ACTUALLY MEASURE THE PROPERTY OF WEIGHT FOR EACH OF THESE OBJECTS AND SEE HOW MUCH THEY DIFFER?

By this time, some child will probably suggest using a beam balance. At any rate, bring out the balance you assembled before class. Briefly review how it works, using the following information as a guide:

1. When one object is placed in one cup and the other object in the other cup, the side that tips down contains the heavier object. You could use this method to arrange all the metal pieces in order from lightest to heaviest, but it would not indicate how much heavier one piece is than another. To find that out, the children must be able to assign a number to the weight of each object.

2. To assign a number to the weight of an object, a standard unit of weight is needed. The children have used the weight of paper cups and of paper clips as standard units of weight before. The object to be weighed is placed in one cup and its equivalent weight in cups and paper clips is placed in the other. Paper clips are used to get a closer measurement than cups provide.

3. The scale is considered balanced when the bob string is lined up with the center of the red region. However, the children should try to get the bob string lined up as closely as possible with the center line of the red region.

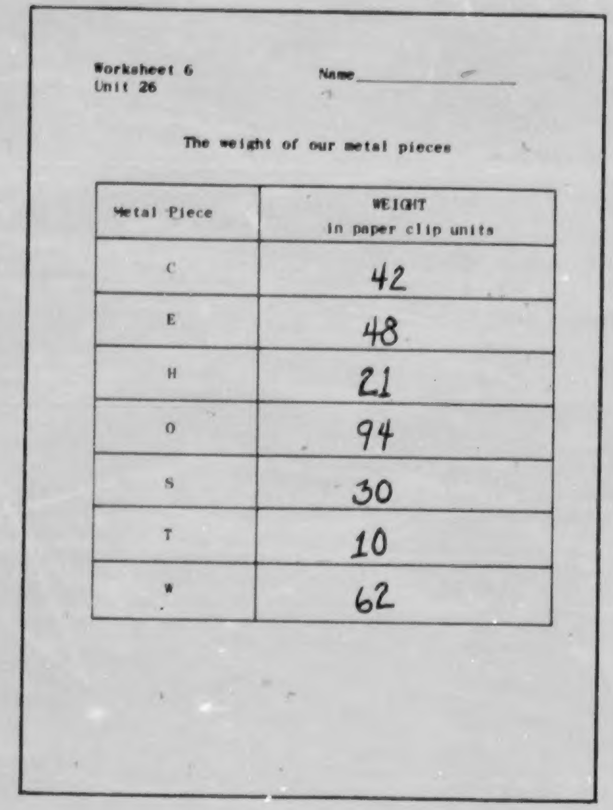
4. The weight of ten #1 paper clips is about equivalent to the weight of one paper cup. Therefore, the weight of an object can be converted from cup units to clip units by

multiplying by ten. For example, an object's weight that is measured as "3 paper cups and 2 paper clips" can be expressed as "32 paper clips." All measurements of weight in this unit are to be converted to the weight of paper clips.

Give the children some practice in weighing with the beam balance. Remind them not to count the paper cups that are parts of the balance, when figuring the weight of an object. Give them some practice in converting cup-clip measurements to clips. When you think they understand how to use the balance and how to figure out the weights in paper clips, ask the children to return to their desks.

Activity B

Divide the class into groups of four. Give each group a beam balance kit. Tell them to use Worksheets 2 through 5 of the Student Manuals to help with the assembling of their beam balances. Go about helping those groups who seem to need it. You probably will have to help most groups to tape the cardboard to the ruler and to place a bit of tape on the back of the ruler for a good balance.



Worksheet 6
Unit 26

Name________________

The weight of our metal pieces

Metal Piece	WEIGHT in paper clip units
C	42
E	48
H	21
O	94
S	30
T	10
W	62

When all the groups have finished assembling their balances, remove strings and tape from the O and W pieces and put them on a centrally located desk or table with the pieces marked C, E, H, S and T. Ask the children to turn to Worksheet 6 in their Student Manuals.

Instruct the groups to take just one piece of metal at a time and weigh it. Each member of the group should write the number of paper clips on his worksheet. One child should then immediately return this piece of metal to the central spot and take another with a different letter. When each group has finished weighing all seven pieces, discuss the results.

Have one child from each group place the beam balance in a storage area. The balances, paper cups and paper clips will be used in later lessons. Keep the metal samples out for the next lesson. Save the worksheets for later use.

Lesson 6: MEASURING THE VOLUME OF METALS

In this lesson the children measure the volume of the seven metal pieces used in the two previous lessons. Before they can do this, however, they must understand what is meant by "volume." MINNEMAST children have studied volume in Units 5, 12 and 19, but in these units volume was defined in two different ways: (1) as the number of units a container can hold, and (2) as the space occupied by the container itself.

In the first case the children were interested in the capacity of a container. The children have measured capacity in several ways. They have counted the number of corks and the number of cubes a container can hold, and the standard liquid measures of volume, such as pints, quarts, gallons, etc.

In the second case, the children were interested in the amount of space a given object or material occupies. Using the first definition of volume, the children were finding out that a four-ounce plastic container had a capacity or volume of four ounces. Using the second definition, the children were finding out the amount of space occupied by the plastic material of which the container itself was made. Obviously the measures of the two kinds of volume are considerably different.

This unit is concerned with the second kind of volume -- the amount of space occupied by a given material. In Unit 19 the children worked with water displacement as a measure of this kind of volume. They dropped a marble into a cylinder containing water up to a certain mark and discovered that the measure of the water rise was equivalent to the volume of the marble. However, the children will probably need a little review in this technique.

When measuring the amount of material of which something is comprised, one must be alert to exactly what the material is. For example, you can measure the amount of space occupied by a balloon when it is blown up and when it is deflated. Obviously, when blown up and submerged in water, the balloon will displace more water than when it is deflated. In both cases one might casually say he is measuring the volume of the balloon, but what is meant by "balloon"? Is it the material used to construct the balloon, or the material plus the air enclosed within it? When the volume of an inflated balloon is measured, you are not measuring the volume of just one material, but of a mixture of materials -- rubber plus air. Other examples of a "material plus air" are: a bag full of popcorn, a sponge, a piece of cotton or a styrofoam ball. When measuring the volume of such objects, it is important to understand what is being measured -- the volume of more than one substance. Clearly define for the children the material they are measuring, because when they start learning about density in the next lesson, it will prevent much misunderstanding.

MATERIALS

-- for Activity A demonstration --

- 3 plastic cylinders with centimeter tape attached (See PREPARATION.)
- 1 cup of water
- 1 medicine dropper
- lump of clay that will displace about 25 millimeters of water in the cylinder
- piece of string about 8 inches long

-- for each group of four (Activity A) --

- 1 tray
- 1 clear plastic cylinder with centimeter tape attached
- 1 medicine dropper
- measuring cup half filled with water

-- for the class --

- metal objects C, E, H, O, S, T, W
- 14 pieces of tape
- 14 pieces of string, each about 8 inches long

-- for each child (Activity A) --

- Worksheet 7

-- for Activity B --

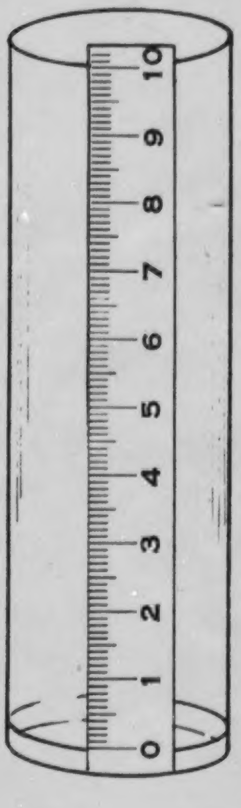
- story puzzle "Nathaniel's Two Balloons," included in the lesson

-- for Activity B demonstration --

- 2 identical balloons
- grease pencil
- clear plastic container (at least pint size, and half-filled with water)
- 1 sponge

PREPARATION

The plastic cylinders used in Activity A measure 4 inches in length and 1¼ inches in diameter. Prepare each cylinder by cutting from your roll of adhesive centimeter tape a length of ten centimeters. Place this along the length of the cylinder. Be sure the zero mark is a little above the base of the cylinder at the point where the cylinder is hollow.



Fill one of your cylinders to the 50-millimeter (5 centimeter) mark and test lumps of clay until you find one of a size that will make the water rise about 25 millimeters. This is the amount of clay you will need for your first demonstration. When testing, put a partially straightened paper clip in the clay so that you can place it in the water and lift it out more easily.

Tape a string to each of the fourteen metal objects. As in the last lesson, these metal pieces can be placed on a centrally located desk where the various groups can take one at a time.

On a tray for each group, place 1 plastic cylinder with cm tape attached, 1 medicine dropper, and one measuring cup half filled with water.

For Activity B, have on hand the materials listed above for your second demonstration.

PROCEDURE

Activity A

Have the children gather around a demonstration table. Briefly review the main points of the two previous lessons. Remind the children that they measured the weight of seven metal pieces in Lesson 5. Tell them that in this lesson they will try to measure the "size" of the pieces. Then say:

> WHEN WE TALK ABOUT THE SIZE OF AN OBJECT, WHAT DO WE MEAN? (We mean how large or how small the object is.)
>
> WOULD A LARGE OBJECT TAKE UP MORE SPACE IN THIS ROOM THAN A SMALL OBJECT WOULD? (Yes.)

Ask whether an elephant would take up more space in the room than an ant would. (Yes.) Then ask why. (Because the elephant is larger in size than the ant.) Then emphasize this point:

> THEREFORE, THE SIZE OF AN OBJECT DETERMINES HOW MUCH SPACE THE OBJECT OCCUPIES.
>
> CAN ANYONE REMEMBER WHAT WORD WE USE TO DESCRIBE THE AMOUNT OF SPACE SOMETHING OCCUPIES? (Volume.)

To show how volume fits in with other measurement studies the children have had, remind them of the following:

1. When you measure a line segment, you measure the property of length.

2. When you stand on a scale, you measure the property of weight.

3. When you measure a region, you measure the property of area.

4. When you measure an angle, you measure its mag.

5. When you measure the amount of space something occupies, you are measuring its volume.

HOW CAN WE MEASURE VOLUME?

Let the children speculate. Some children may remember some of the methods used in previous units. Now explain how sometimes the word "volume" can be used to describe the space that is occupied in two different ways. Take the lump of clay you have prepared in advance and mold it into a cup shape. Say that you could measure the amount of space contained in this clay cup.

WHEN WE DO THIS, WE ARE INTERESTED IN THE CAPACITY OF THE CONTAINER -- HOW MUCH IT WILL HOLD.

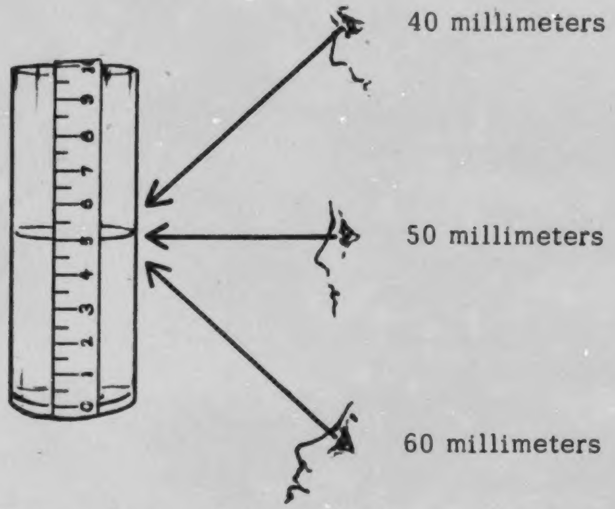
Have the children discuss with you various ways this kind of volume could be measured -- with pints, cups, quarts, ounces, number of corks, etc. Then fill the clay cup with water. Pour the water from the clay cup into a cylinder that has cm tape attached. Record on the chalkboard the number of millimeter units the volume (capacity) of the clay cup measures in the cylinder. Discuss with the class several other examples of situations where the capacity of a container is the type of volume they would be interested in measuring, such as a quart of milk, a box of crackers, a glass of juice.

Now say that at other times people are interested -- not in volume as the measurement of what a container will hold -- but in volume as the amount of space the container itself occupies (takes up). Now mold the clay cup into a solid ball. Tell the class that this time you want to measure the amount of space (the volume) that the clay material of which the cup was made occupies.

HOW CAN WE MEASURE THE AMOUNT OF SPACE THIS CLAY OCCUPIES?

Hold up the ball of clay. Perhaps some child will recall the water displacement activities from previous units and can demonstrate how the calibrated cylinder could be used. If not, demonstrate by putting water into the plastic cylinder up to the 5-centimeter mark. Show an empty cylinder to the children and tell them that each of the centimeter marks represents 10 millimeters. Therefore, each of the small units on the tape represents one millimeter. Show them how to put in or take out small amounts of water with the medicine dropper in order to get the level wanted. Then show them how to hold the container with the top of the water at eye level to get a correct reading. Ask someone to say how many millimeters of water you have in the cylinder when it is at the 5-centimeter mark. (50 millimeters.)

Demonstrate how much error can be made in a reading by looking at the height of the water from above or below eye level.



Have the children check to see that the water in your cylinder is at the 50 millimeter mark. Now insert one end of a partially straightened paper clip into the clay ball and lower it into the cylinder. (The clay ball must be completely submerged.) Ask a child to read the new water level. Record what happened on the chalkboard:

Height of water at start ≐ 50 millimeters*
Height of water with clay ball in it ≐ 75 millimeters
Amount of water displaced by clay ≐ 25 millimeters

The children should realize that the amount of water that was displaced by the clay is equivalent to the amount of space that is taken up by the clay (the volume of the clay).

> SINCE WE CAN MEASURE THE VOLUME OF CLAY BY WATER DISPLACEMENT, COULD WE ALSO USE THIS METHOD TO MEASURE THE VOLUME OF EACH OF OUR METAL PIECES? (Yes.)

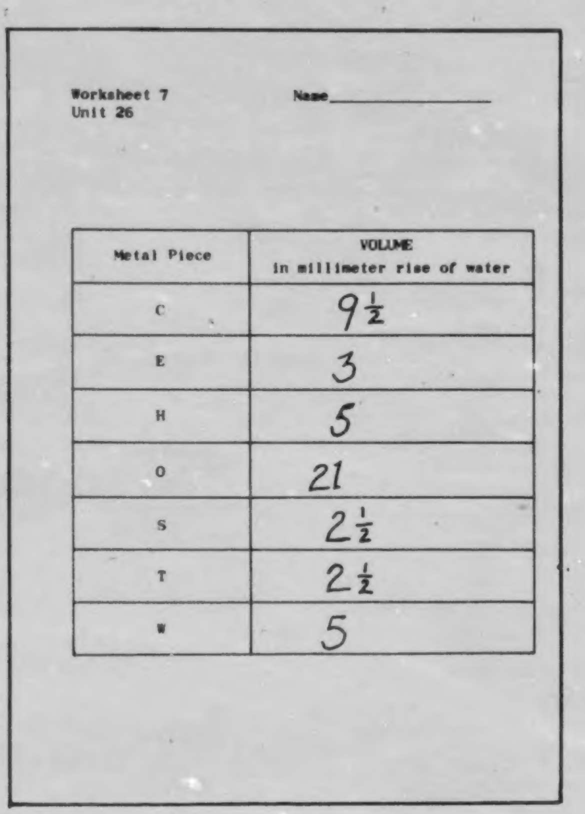
Tell the children they will be working in the same small groups as in the previous lesson to measure the volume of the metal pieces. Have each group take a tray of the materials you have prepared. Place the metal pieces (with strings attached) in a central location. Instruct the groups to take one metal piece at a time (as they did in the last lesson), measure and record on Worksheet 7 its volume in millimeters displaced and then return it immediately so that others can use it.

Remind the children to check the water level after each measurement, because some water may cling to the metal when it is removed. With their medicine droppers, they can easily add a few drops. Tell them that the water level at the start should always be 50 millimeters. If the children seem to be having trouble with water running too freely out of the medicine droppers, suggest that they try filling the droppers to the halfway mark or a little beyond. Then the drops can be squeezed out more slowly.

Each child should record the group's measurements on Worksheet 7. Go about the room as the groups are working, checking to see that they are reading water levels at eye level,

* The symbol (≐) is read "appears to be the same as."

starting each time at the 50 millimeter mark, etc. As each group concludes its work, discuss the results with them. If their results seem to be too far out of line, suggest that they remeasure. Ask the groups to clear up the materials, when finished, and to be sure to save the worksheets for the next lesson.



Worksheet 7
Unit 26

Name_______________

Metal Piece	VOLUME in millimeter rise of water
C	9½
E	3
H	5
O	21
S	2½
T	2½
W	5

Activity B

Place on the demonstration table the following materials: two identical balloons, grease pencil, clear plastic large container (preferably at least a pint size) and a sponge.

Read the following story puzzle to the children. When you have finished, ask each child to write on a piece of paper why he thinks the boy in the story got such different results.

The story puzzle:

NATHANIEL'S TWO BALLOONS

Nathaniel had two balloons that he bought at the store. The balloons were both red. They were both made of the same kind of rubber. They both weighed the same amount. They even came packed in the very same bag. Nathaniel thought he would like to measure and compare the volumes of the two balloons to see if they were the same, too. He brought out two glasses that were exactly alike. He put the same amount of water in each glass. Then he carefully marked the water level on each glass. He put the glasses close together and saw that the water level marks were at exactly the same height. Then Nathaniel started to measure the volume of the two balloons.

He put one balloon in the first glass and saw that the water hardly rose in the glass at all. It was hard for him to mark the new water level because it was so close to his starting mark.

But when Nathaniel pushed the second balloon down into the second glass, the water rose so high it nearly reached the top.

. . . . . .

Now ask the class:

> WHY DO YOU THINK NATHANIEL GOT SUCH DIFFERENT MEASUREMENTS OF VOLUME FOR THE TWO BALLOONS? COULD HE REALLY HAVE BEEN MEASURING THE SAME KIND OF VOLUME IN BOTH GLASSES? OR WAS HE MEASURING A DIFFERENT SORT OF THING IN EACH GLASS? WHAT DO YOU THINK NATHANIEL DID TO GET SUCH DIFFERENT MEASUREMENTS FOR TWO BALLOONS THAT WERE SO MUCH ALIKE WHEN HE BOUGHT THEM?

Ask the children to commit themselves by writing their answer to the last question on a piece of paper. When everyone has done this, have the children gather around the demonstration table.

Call on various children to demonstrate why they think Nathaniel got two such different measures of volume for the "balloon." Some child will probably eventually discover that a balloon, when blown up, displaces much more water than the deflated balloon. When this happens, ask the class which would be the correct measure of the balloon's volume. The children should see that their answers all depend on what is meant by the word "balloon." Does it mean the material -- the rubber -- that is used to make the balloon? Or does it mean the rubber plus the air inside of it? The children should realize that it is very important, when measuring volume, to define clearly their material, so that someone will not misunderstand what is meant.

Another example of a material-plus-air volume is a sponge. You can demonstrate this by immersing the sponge in the water. As the sponge absorbs the water, air bubbles will float to the surface. The children should see that the water level is higher when the sponge is first put in the water, but rapidly decreases as the air in the sponge is replaced by water.

The children may want to discuss other examples where the material is easily obscured by the way the words are used: a bag of popcorn, for example. What is meant when someone says that? Does he mean only the substances that make up the corn, or the corn plus the air in the bag between the kernels? Cotton candy, styrofoam, cotton balls, etc., are other examples of materials plus air that the children might want to talk about.

SECTION 4

PROPERTY OF DENSITY

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SECTION 4 THE PROPERTY OF DENSITY

PURPOSE

- To have the children make a number of hypotheses about volume/weight relations.
- To have them check these hypotheses on several different kinds of materials.
- To have the children learn that volume/weight relations can be graphed from the ordered pairs derived from measuring the volume and the weight.
- To have them see that, by measuring the volume and weight of an unknown material and plotting this point on a graph that shows the density slope of known materials, they can come to some conclusions about the density of the unknown.

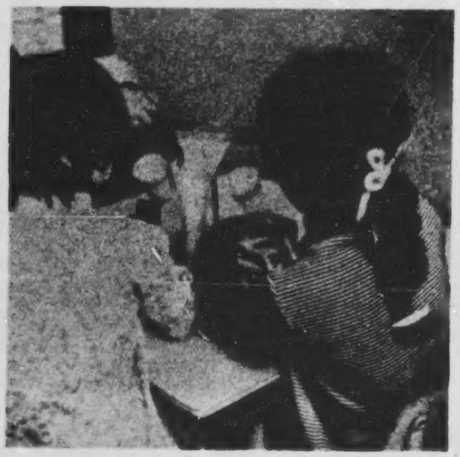
COMMENTARY

In the two previous lessons the children collected volume and weight data on Worksheets 6 and 7 which they will now transfer to Worksheet 8 (Lesson 7). Because the data concerns only unknowns, the children will now turn to a very familiar material -- clay -- and gather some data about that. Then they return to graphing volume/weight data of metals and of other materials.

By the end of Lesson 10, the children should understand that volume and weight measurements, when plotted on a grid, can be useful in identifying an unknown material, especially if they already have made graphs of many known materials. They measure the volume and weight of an unknown substance and plot this ordered pair on a grid with graphs of other substances. The children can tell by where the plotted point falls whether their material is of the same density as another material, whether it may be a mixture of several materials, or whether it may be a new material which has not yet been graphed.

Emphasis in this unit has been on having the children study a number of properties of different materials in order to try to identify them. By observing a piece of metal, by classifying it with others in a scratch test, and by figuring out its density, the children have been given a number of properties by which to identify it. By observation, they have noted the properties of color, shape and size. By the scratch test, they have found out the property of hardness. By using beam balances and water displacement equipment, they have studied the properties of weight and volume and their relation to each other (density).

The word "density" is not important. What is important is for the children to see that, for any given material, there is a definite relation between its volume and its weight. If measurements are ideally accurate, any amount of a given material should provide measurements of volume and weight that will all fall on a given density line.



Lesson 7: VOLUME/WEIGHT RELATIONS

The purposes of this lesson are to have the children: (1) see that if they have equal volumes of the same material, the weights will also be equal, (2) discover that when they add more of a given material to an initial sample, the volume and the weight increase proportionally, and (3) discover that when the ordered pairs developed from volume/weight measurements for a given material are plotted on a grid, the points plotted fall on a straight line through the origin.

In Activity A the children briefly review the work they have done in the last two lessons. They discuss the data they have recorded (about the metal pieces) on Worksheets 6 and 7. As a class they check and correct the data and agree on more accurate measurements to record on Worksheet 8. Then the children are asked if there is anything in these data that would help them see a relation between volume and weight, or would help them identify any of the metals. The children can observe that, though metal pieces S and T have the same volume, they have different weights. They see that this is also true of metal pieces H and W. These observations seem to lead to the idea that S and T may be made of different materials, and that H and W may also be made of different materials, but it is not the kind of information that lends itself easily to identifying any of the materials. You now make the suggestion that if the children were dealing with a material that they were already familiar with -- such as clay -- and measured its volume and weight, they might be able to discover some more meaningful relation between the volume and weight measurements.

In Activity B the children measure the volume and weight of two balls of clay that are as nearly identical as you can make them. They make a tentative hypothesis from the results, namely: that if two identical objects are made of the same material and are alike in size, they will be alike in weight, and vice versa. Then they measure the volume and weight of three clay balls of sizes and weights that are proportional to one another. Ball 1 weighs 2 paper cups and displaces 7 mm of water, ball 2 is double the size and weight of ball 1. It weighs 40 clips and displaces 14 mm of water.

Ball 3 is triple the size of ball 1. It weighs 60 clips and displaces 21 mm of water. From this experiment, the children see that, if the same material is used, and the weight of an object is doubled or tripled, its volume will also be doubled or tripled. (This is only a hypothesis that will be tested again, with other materials in other lessons.) The children record the measurements for the three clay balls on Worksheet 9, decide on the ordered pairs, and graph the three points on a grid (Worksheet 10). This graphing leads to the discovery that the three plotted points all fall in a straight line from the origin (0, 0). The children are then asked whether or not the measurement of other pieces of clay would fall on this same straight line.

In Activity C each group is given a stick of clay (of exactly the same kind used in the demonstrations) and equipment for measuring volume and weight. Each group breaks the clay into pieces of any size they wish. The only restriction is that the pieces must be of a size that can be measured with the equipment they have. Each group gathers the volume and weight data for its pieces, records the data on Worksheet 9 and graphs it on Worksheet 10. If the children have been careful in their measurements, they will now see that, no matter what volume or weight each piece of clay was, it seems to fall on the same straight line as the three points already plotted. Another hypothesis can now be made: measurements for any piece of this same material will fall on the same straight line. The lesson ends with the question, "Will the measurements of volume and weight for other materials also fall on this same straight line through the origin (0,0)?" The children will try to answer the question in the next lesson.

MATERIALS

-- for Activity A --

- metal pieces C, E, H, O, S, T and W
- 1 beam balance
- 1 water displacement set (See page 38.)
- Worksheets 6, 7 and 8

- 1 stick of clay

-- for Activity B --

- 2 identical clay balls, each weighing 4 paper cups (40 paper clips)
- 1 clay ball, weighing 2 paper cups (20 paper clips)
- 1 clay ball, weighing 6 paper cups (60 paper clips)
- 3 beam balances
- 3 water displacement sets
- 4 straightened paper clips
- Worksheets 9 and 10
- rulers and pencils

-- for each group of four (Activity C) --

- volume and weight measuring equipment
- stick of clay
- 4 straightened paper clips
- Worksheets 9 and 10

PREPARATION

It is important that all the clay used in this lesson be of exactly the same kind (even in color), so that the children can be sure they are always measuring the same material. There is little preparation for Activity A, which is largely discussion and demonstration. You will need only one set each of the volume and weight measuring equipment, the metal pieces from the previous lessons, and the worksheets.

For Activity B, you will need three volume and weight measuring sets and the following carefully prepared clay balls:

1 ball with volume of exactly 7 mm and
weight of 2 paper cups (20 clips)
2 balls, each with volume of 14 mm and
weight of 4 paper cups (40 clips)

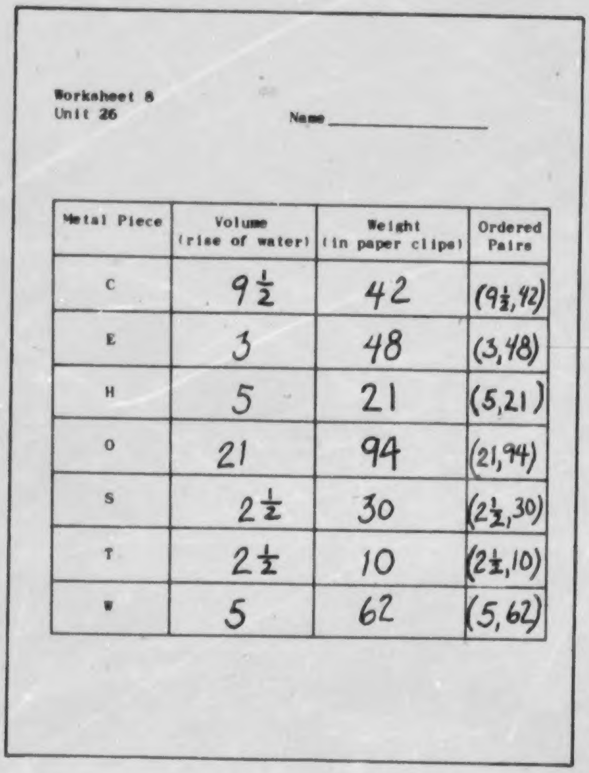
1 ball with volume of 21 mm and weight
of 6 paper cups (60 clips)

Activity C requires the same equipment the children used in previous activities, but with clay instead of the metal pieces.

PROCEDURE

Activity A

Briefly review with the children what they did in the two previous lessons. Remind them that (1) they have been gathering weight and volume data about seven pieces of metal, and that (2) they were hoping to find in this information some relation between weight and volume that might help in some way to identify the metals. Then ask the children to turn to Worksheet 8 in their Student Manuals. On the chalkboard, quickly sketch a chart like that on the worksheet. [Note that volume data is listed to the left of weight data. This is done so that, when the children eventually graph their ordered pairs, volume will be on the over (x) axis and weight will be on the up (y) axis.]



Worksheet 8
Unit 26

Name ____________________

Metal Piece	Volume (rise of water)	Weight (in paper clips)	Ordered Pairs
C	$9\frac{1}{2}$	42	$(9\frac{1}{2}, 42)$
E	3	48	(3,48)
H	5	21	(5,21)
O	21	94	(21,94)
S	$2\frac{1}{2}$	30	$(2\frac{1}{2}, 30)$
T	$2\frac{1}{2}$	10	$(2\frac{1}{2}, 10)$
W	5	62	(5,62)

Now tell the children that, working together as a class, they are going to help you decide on the data to be used on Worksheet 8. Have them tear out Worksheets 6 and 7 so that they can provide the data as you call for it. Ask for the volume data, then the weight data, and then for the ordered pair. Discuss one metal at a time.

If there are differences in the data from one group to another, the data may have to be checked before you fill it in on the chalkboard chart. Talk with the children about some of the causes for error, such as:

1. possible differences or defects in the measuring devices
2. differences in the height of the water at the start
3. misreading the water level at the finish
4. subtraction mistakes in figuring units of water displaced
5. hasty or erroneous recording

Explain that because there are so many possibilities for error when measurements are taken, you want to be sure all the data they put on Worksheet 8 is as accurate as possible. That is why you are having the whole class participate and check.

When all of the data on the chalkboard has been agreed upon, ask the children to copy it onto Worksheet 8. You should now collect and throw away all copies of Worksheets 6 and 7, so that the children will have only the data on Worksheet 8 when they do the graphing of the ordered pairs in the next lesson.

Now discuss the data on the chalkboard. Ask the children if they notice any volume/weight relations that might help them to distinguish one kind of metal from another, or help identify any of the metals. Some child will probably notice that metals S and T have the same volume, but different weights. Another may notice that this is also true for metals H and W. Ask if the fact that two materials have the same volume, but different weights, could perhaps be an indication that they are not of the same material. (Yes.) Ask if this would seem to indicate that equal amounts of the same material should have equal weights. (Yes.) Tell the children that it might be helpful in analyzing their data if they knew more about the volume/weight relations for one particular kind of material -- a known material, like clay.

Hold up a stick of clay. Break it into several pieces of different sizes. Then ask:

WHAT PROPERTY DO ALL THESE PIECES HAVE IN COMMON?

(They are all made of clay; they are all made of the same material.)

Then say:

IF WE CAN FIND SOME RELATION BETWEEN THE VOLUME AND WEIGHT MEASUREMENTS OF ALL THESE PIECES OF CLAY, MAYBE IT WILL TEACH US MORE ABOUT OUR DATA FOR THE METAL PIECES.

Activity B

Have the class gather around a demonstration table. Show the two balls of clay that you have previously prepared and know to be of identical size and weight. (These each weigh 4 paper cups or 40 paper clips, and displace 14 millimeters of water.) Ask the children to describe some of the properties of the two balls. (They are of the same color, and the same material, and they appear to be the same size.)

HOW CAN WE MAKE SURE THAT THESE TWO BALLS OF CLAY ARE THE SAME SIZE? (Measure the amount of water each displaces.)

Put a straightened paper clip into each of the clay balls, and then select two children to measure the volume of the balls. Ask one child to do the actual measuring and the other to check for accuracy at each step. Write the result (14 millimeters displaced) on the chalkboard. Then ask:

IF THE VOLUMES ARE THE SAME, WHAT RELATION WILL THE WEIGHTS HAVE TO ONE ANOTHER? WILL THE WEIGHTS BE THE SAME, OR DIFFERENT? (Probably most children will predict that the two balls will weigh the same.)

HOW CAN WE CHECK TO BE SURE? (We will have to weigh them.)

Choose two children (one weigher, one checker) to measure the weight of each ball on the beam balance. The balls should balance each other, and each should weigh about

4 paper cups or 40 clips. Record the weights on the chalkboard. Ask the class what hypotheses they might wish to consider at this time. Write their hypotheses on the chalkboard. For example:

> IF MADE OF THE SAME MATERIAL, OBJECTS OF EQUAL VOLUMES WILL HAVE EQUAL WEIGHTS.
> IF MADE OF THE SAME MATERIAL, OBJECTS OF EQUAL WEIGHTS WILL HAVE EQUAL VOLUMES.

Make sure that the children understand that the above are only hypotheses, and that they will have opportunities to test them with other materials in other lessons.

Now put one of the identical clay balls away and bring out the smaller ball (weighing 2 cups) and the larger ball (weighing 6 cups) that you have prepared. Ask the class to tell how the three balls are alike and how they are different. They should say that all are of the same material, but of different sizes. Then ask:

> IF THESE BALLS OF CLAY ARE DIFFERENT IN SIZE (VOLUME), WILL THEY BE DIFFERENT IN WEIGHT? (Yes, if the hypotheses just made are true.)

Now have the children compare the smallest ball of clay with the largest, and ask:

> WHICH WILL WEIGH MORE, THE LARGEST BALL OR THE SMALLEST? (The largest.)

Have the children check this answer with the beam balance. The larger ball will pull the balance arm down, and is therefore the heavier. Write this generalization on the chalkboard:

> FOR THE SAME MATERIAL, THE GREATER THE VOLUME, THE GREATER THE WEIGHT.

Now hold up the medium-sized ball and the smallest ball of clay and ask:

> IF THIS BALL HAS TWICE THE VOLUME OF THIS BALL, HOW WILL THEIR WEIGHTS COMPARE? (Most children will

probably say that the weight of the larger ball is double that of the smaller one.)

HOW COULD WE CHECK TO SEE IF THIS IS TRUE?

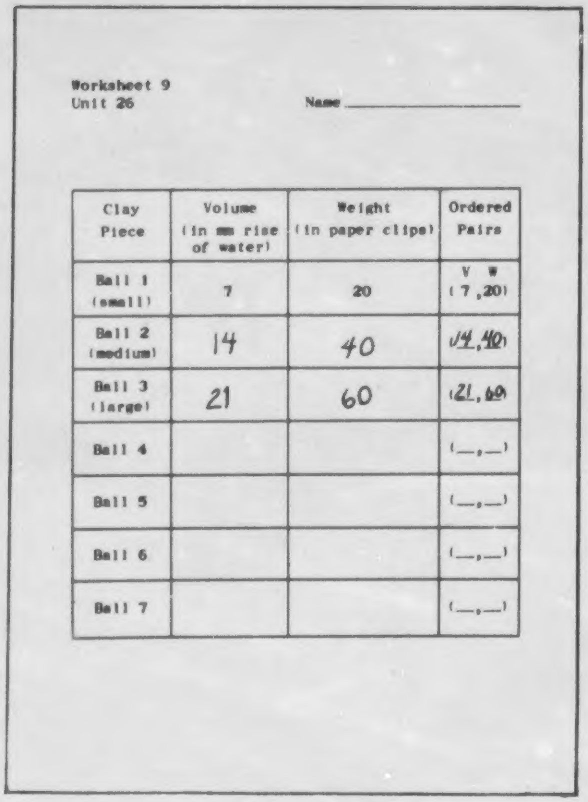
Using three beam balances and three water displacement sets, have three children measure the volume and weight of each ball of clay. You may want to assign a partner to each child as a checker. When the children have finished, record their data on a chalkboard chart like this:

	Volume	Weight	Ordered Pairs
Ball 1 (Small)	7	20 clips	(7, 20)
Ball 2 (Medium)	14	40 clips	(14, 40)
Ball 3 (Large)	21	60 clips	(21, 60)

The children should see that as the volume doubled and tripled, the weights doubled and tripled also. Record this generalization on the chalkboard:

> IF THE VOLUME OF A GIVEN MATERIAL IS INCREASED A CERTAIN NUMBER OF TIMES, THE WEIGHT WILL BE INCREASED BY THAT SAME NUMBER OF TIMES.

Now discuss the fact that in earlier units, the children found it helpful to graph their data in order to understand it better. Suggest that it may be helpful to graph the clay data on a grid, too. Discuss how this could be done, i.e., have volume along the over axis, and weight along the up axis. Develop with them the ordered pairs for each ball of clay, and list these on the chalkboard chart.

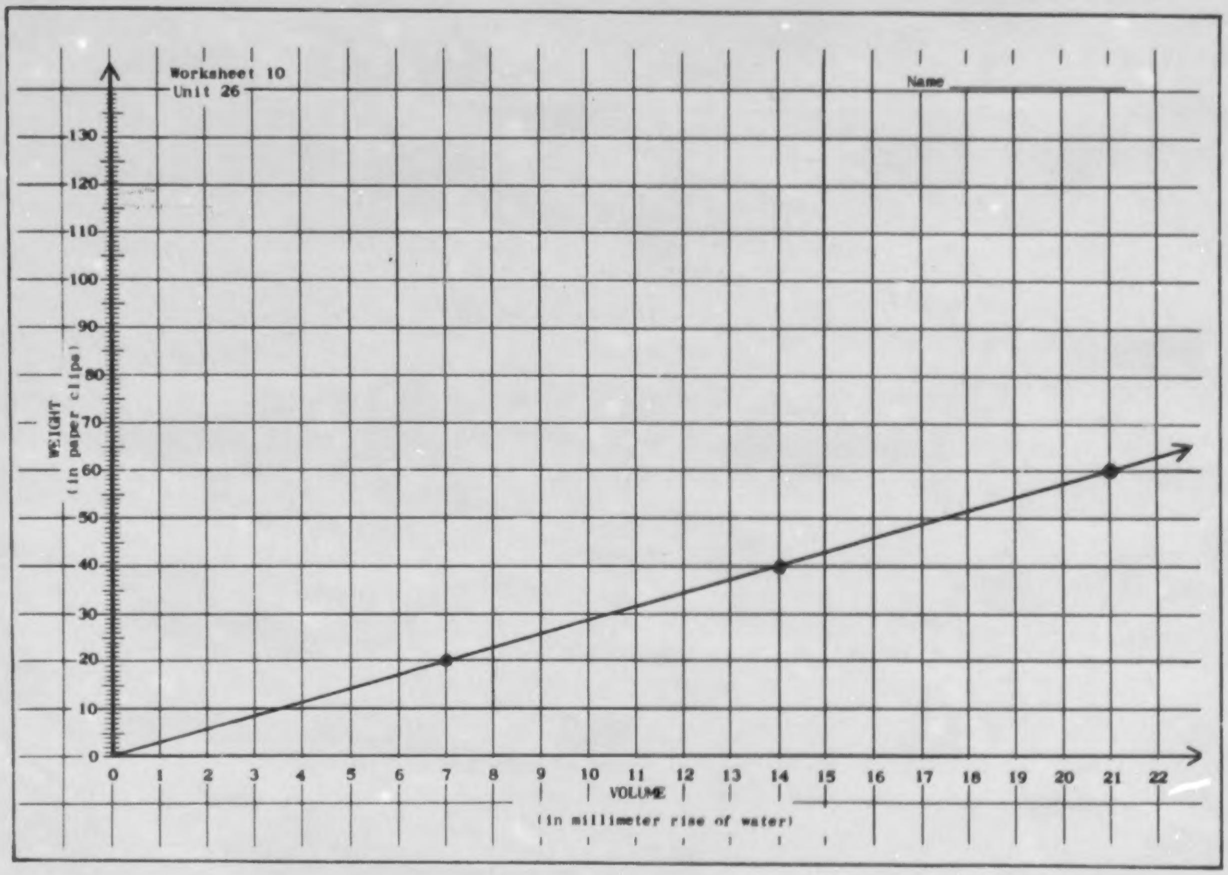


Worksheet 9
Unit 26

Name ____________

Clay Piece	Volume (in mm rise of water)	Weight (in paper clips)	Ordered Pairs
Ball 1 (small)	7	20	V W (7,20)
Ball 2 (medium)	14	40	(14,40)
Ball 3 (large)	21	60	(21,60)
Ball 4			(__,__)
Ball 5			(__,__)
Ball 6			(__,__)
Ball 7			(__,__)

Have the children return to their seats and open their Student Manuals to Worksheet 9. Ask them to copy the data for the clay from the chalkboard chart to their worksheet. They should then fold out Worksheet 10 and graph the three ordered pairs on it.



When the children have finished graphing, ask them if they notice any interesting relation among the three points. Some students will probably notice that all the points appear to be located on a straight line. Using pencils and rulers, ask the children to draw the straight line that connects the three points and extends beyond them in both directions. This line should start at the origin (0,0) and go through the three points to the righthand margin of the worksheet. When the children have done this, ask:

> IF WE PLOTTED OTHER VOLUME AND WEIGHT DATA FOR OTHER PIECES OF THIS SAME KIND OF CLAY, WILL THEIR ORDERED PAIRS FALL ON THIS LINE, OR WILL THEY FALL SOMEWHERE ELSE?

Activity C

Provide each group of four children with equipment for measuring volume and weight, and give each group a stick of exactly the same kind of clay used in the previous activity. Tell each group they may break their stick of clay into four pieces of any size that is measurable with their equipment. Remind the children that if they have to start with less water in a cylinder in order to submerge a rather large piece of clay, they should write down the starting level very carefully, so that when they do their subtracting they will not forget what the level was. Remind the children to insert partially straightened paper clips in the clay when measuring the volume. Ask the groups to try to be as accurate as possible, and to check each measurement very very carefully. Each child should record the measurements for each of the four balls on Worksheet 9, figure out the ordered pairs, and then plot the points on Worksheet 10.

When all the groups have plotted their data, have a spokesman from each group report their findings to the class. Allowing for measurement error, most of the ordered pairs should fall on the original line. Have the children now label that line, "Clay." Then write on the chalkboard:

> IF WEIGHT AND VOLUME MEASUREMENTS OF A CERTAIN MATERIAL ARE PLOTTED ON A GRID, ALL THE POINTS WILL FALL ON A CERTAIN STRAIGHT LINE THAT STARTS AT THE ORIGIN (0,0).

Let the children know that, so far, this is only a hypothesis that appears to be true when they used different amounts of the same kind of material -- namely, clay. Then ask:

> DO YOU THINK THAT THE ORDERED PAIRS WE MIGHT GET FROM MEASURING THE VOLUME AND WEIGHT OF A DIFFERENT KIND OF MATERIAL WOULD ALSO FALL ON THIS SAME STRAIGHT LINE?

Ask the children to think about the question. Then tell them that they will be investigating this problem in the next lesson.

Lesson 8: CHECKING VOLUME/WEIGHT RELATIONS

The purposes of this lesson are: (1) to have the children check, with other materials, the hypotheses they made from measurements of the volume and weight of clay; (2) to have the children learn to distinguish one material from another by looking at the slopes of the lines graphed for each material; and (3) to have them check predictions made from volume/weight graphs with the hardness tests made for the same metals in Lesson 4.

Using three different kinds of metals, the children find that the following hypotheses they made about clay hold true for each of the new materials:

1. For two objects of the same material, if they have equal volume, they also have equal weight.

2. If the volume of a given material is doubled, the weight is also doubled.

3. For each material, the points plotted from the ordered pairs of volume and weight measurements will fall in a straight line from the origin.

The children will also make a new hypothesis: If a point plotted from an ordered pair does not fall on the straight line for a given material, it is probably a different kind of material from that represented by the line.

MATERIALS

-- for your demonstration (Activity A) --

- 1 set of volume and weight measuring equipment
- 3 metal pieces marked C
- 2 metal pieces marked W
- cellophane tape
- 2 pieces of string about 8 inches long

-- for each child (Activity A) --

- Worksheets 8 and 10

-- for each group of four (Activity B) --

- 1 set of volume and weight measuring equipment

-- for the class (Activity B) --

- metal pieces A, D, K and L (and later, pieces B, G, and P)

-- for each child (Activity B) --

- Worksheets 10 and 11

PREPARATION

Arrange the materials for each group of four on a tray for Activity B. Place the metal pieces they will use in this activity in a convenient place. (Set metal pieces B, G and P aside to introduce near the end of the lesson.)

PROCEDURE

Activity A

For your demonstration have ready one set for measuring volume and weight, three C pieces of metal and two W pieces, some tape and some string. Have the children gather around the demonstration table and briefly discuss with them some of the hypotheses made in the previous lesson:

When measuring two objects of the same material:

1. If they have the same volume, both will have the same weight.

2. If the volume of one is greater, its weight will be greater.

3. If the volume of a material is doubled, its weight will be doubled.

4. All volume/weight measurements, when plotted, will fall on the same straight line if the material is the same for all ordered pairs. (This line will go through the origin.)

Tell the children that you would like to have them check these hypotheses and see if they hold true for a kind of material other than clay. Hold up two of the C pieces. Show the children that each is marked "C" and so you presume they are both made of the same material. Have a few children compare the two pieces and see that their volumes are the same. Then ask:

> SINCE THE VOLUMES OF THE TWO C PIECES SEEM TO BE THE SAME, SHOULD THEIR WEIGHTS BE THE SAME ALSO? (Yes, if their hypothesis about the clay is true for other materials, too.)

Have a child check the weights of the two pieces on the beam balance. The class will agree after this checking that so far the hypothesis seems to be holding true for this new material.

Now tape two C pieces together and bring out a third C piece. Ask the children how the two taped pieces compare in volume and weight with the single piece. (The volume and weight of the taped two C pieces should be double that of the single C piece.) Have a child check the water displacement measurement and another check the weights. They should get these results:

	Volume	Weight
C (alone)	9½	42
2C (taped together)	19	84

Now the third hypothesis (that if the volume of a material is doubled, the weight doubles) seems to hold true of this material, too. Ask:

> DO YOU THINK, IF WE PLOTTED THESE ORDERED PAIRS ON A GRID, THAT THE POINTS FOR THIS MATERIAL WOULD FALL ON A STRAIGHT LINE THROUGH THE ORIGIN?

Let the children speculate. Then ask how they could find out. [By graphing the two ordered pairs (9½, 42) and (19, 84).] But before the children do the plotting of these points, ask them if they think the points for material C will fall on the clay line. Then have the children return to their desks and plot the two ordered pairs on the grid on Worksheet 10.

When the children have finished plotting the two points, discuss their discoveries, namely: that the two points for this metal do not fall on the clay line, but appear to be lying on a straight line of their own that also goes through the origin.

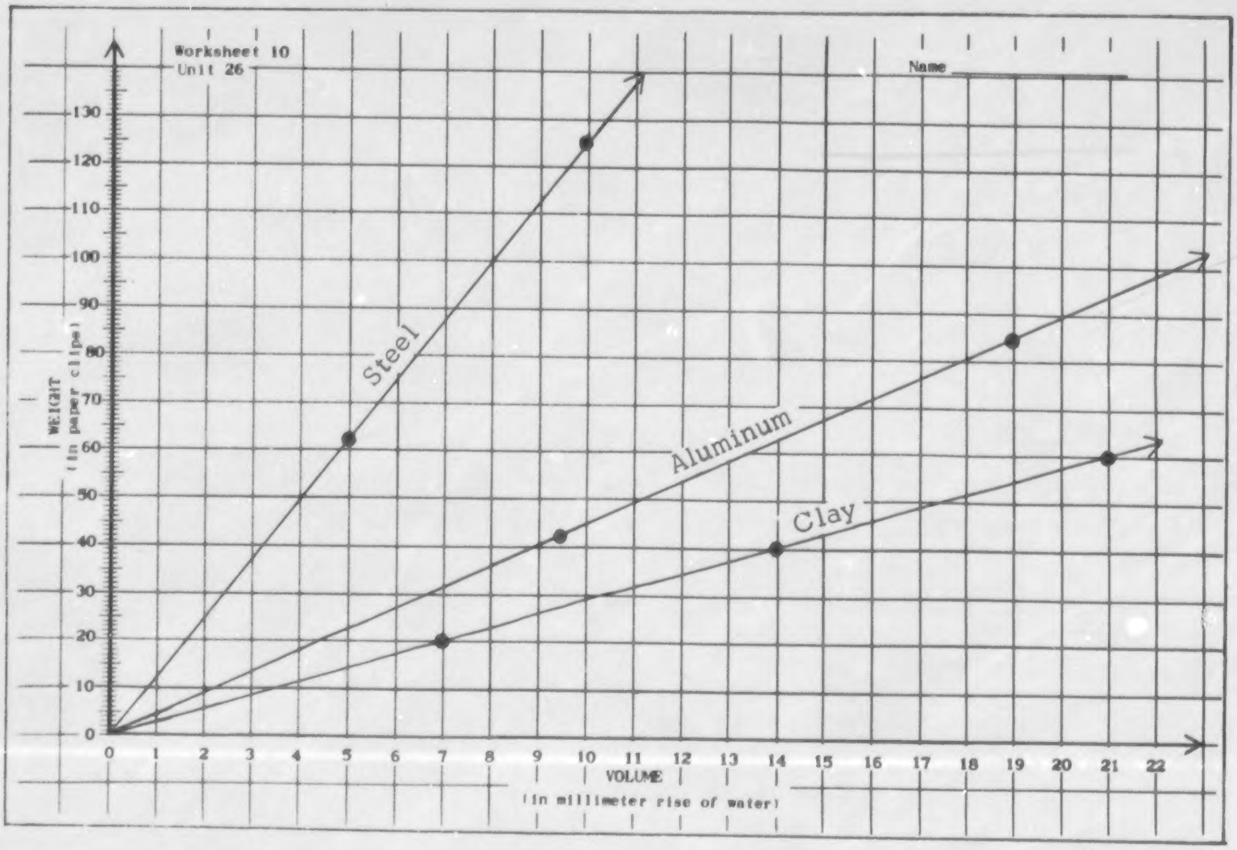
Now ask the children whether or not any of them know the name of the material in metal piece C. (They probably will not be able to identify it by name.) Explain that the metal is called "aluminum". You might like to know that the word "aluminum" comes from the Latin word "alum" meaning "an astringent." It was originally extracted by Oersted from a fused alum salt (probably aluminum sulfate). Write "aluminum" on the chalkboard and have the children write it along the new line on their worksheets.

After the children have drawn and labeled the aluminum line, remind them that even though their hypotheses have proved to be correct for two different materials, a better test would be to try still another kind of material. Ask the children to look at Worksheet 8 and notice the volume and weight data they have gathered for metal piece W. Quickly demonstrate that two W pieces balance each other -- they weigh the same amount.

On the chalkboard write the volume/weight ordered pair for metal W (5, 62). Ask the class what the ordered pair for two W pieces taped together would be if the hypothesis that doubled volume means doubled weight is true (10, 124). Tape the two W pieces together and have one pair of children measure the volume, and another pair measure the weight. Allowing for measurement error, the two W pieces should be double in volume and double in weight, as predicted.

Now you want the children to test the fourth hypothesis -- that the points plotted from ordered pairs of the measurements of volume and weight for two objects made of the same material will fall on a straight line. Have the children plot the two ordered pairs [(5, 62), (10, 124)] on Worksheet 10. But, before they do this, ask them to predict whether or not the points will fall on the clay line or on the aluminum line, or somewhere else. Some children may say that if the material in piece W is not aluminum (it obviously is not clay), the points will probably not fall on the aluminum line. Now have the children plot this new line.

Ask if anyone can guess what the name of the third material is. (They should not be able to identify it from the information available to them so far.) Then tell the class that this material is known as "steel." Have them write steel on the new line they drew through the plotted points and the origin.



Each child should now have three different lines going through the origin, and you are ready to help them make the following generalizations:

1. That volume/weight points plotted from ordered pairs for a given material will fall on a straight line through the origin.

2. That if an ordered pair does not fall on a straight line for a given material (allowing for measurement errors), the new point represents a different kind of material.

Ask the children if they think they could use the volume/weight relations they have already plotted to help them identify the set of metal pieces they worked with earlier. (Yes, if some of them were of the materials already plotted, the children could identify those that fell on certain lines. They would have to plot the data on their grid.) Have the children complete the chart on Worksheet 8 by writing the ordered pairs for the volume/weight data. When they have done this, they should tear out Worksheet 9 so that Worksheet 8 faces Worksheet 10 (their grid). Now it is easy to plot the ordered pairs from Worksheet 8 on Worksheet 10. Ask the children to label each point with the letter that is on the metal piece.

When everyone has completed graphing the ordered pairs, discuss the children's observations:

1. Points S and W fall on the same line, and therefore may be made of the same material -- steel.

2. Points C, O, H and T all seem to fall on or near the aluminum line.

3. Point E is close to the steel line, but is far enough away to represent, possibly, a different material.

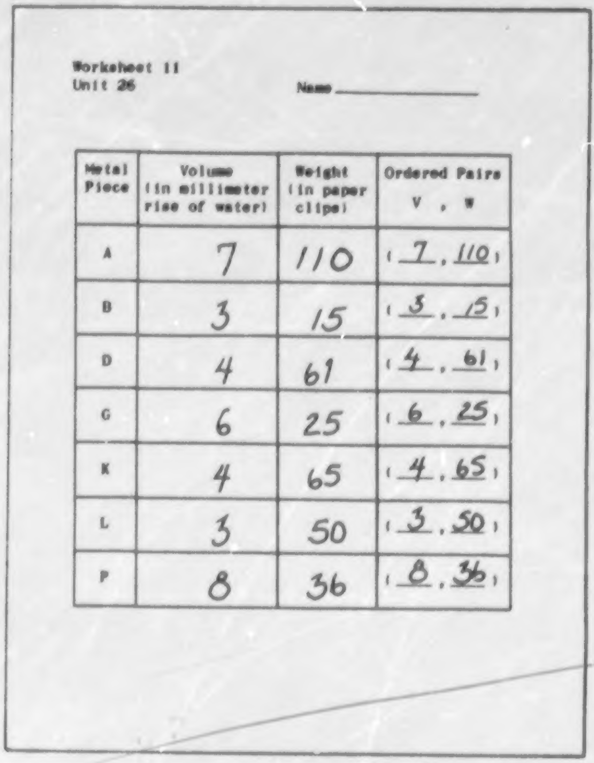
These observations should be compared with the observations made when the metal peices were tested for hardness. The ordering by hardness is shown on the next page.

Softest	Next Hardest	Hardest
E	H, C, O, T	S, W

According to the hardness test, E was softer than the other metal pieces. Thus it appears to be a different material than the others. Have the class draw a new line that goes through the origin and point E. Mention to the class that every test for a property seems to bring more information about a material, so the more tests they can find to do, the better. However, they have not yet learned enough tests to identify unknown materials.

Activity B

Tell the class that you have a few more metal pieces (A, D, K and L) for them to measure for volume and weight. Ask the children to work in the same groups of four as they did before. Each group should find the volume and weight of each of the new pieces. These should be recorded on Worksheet 11, then plotted on Worksheet 10.



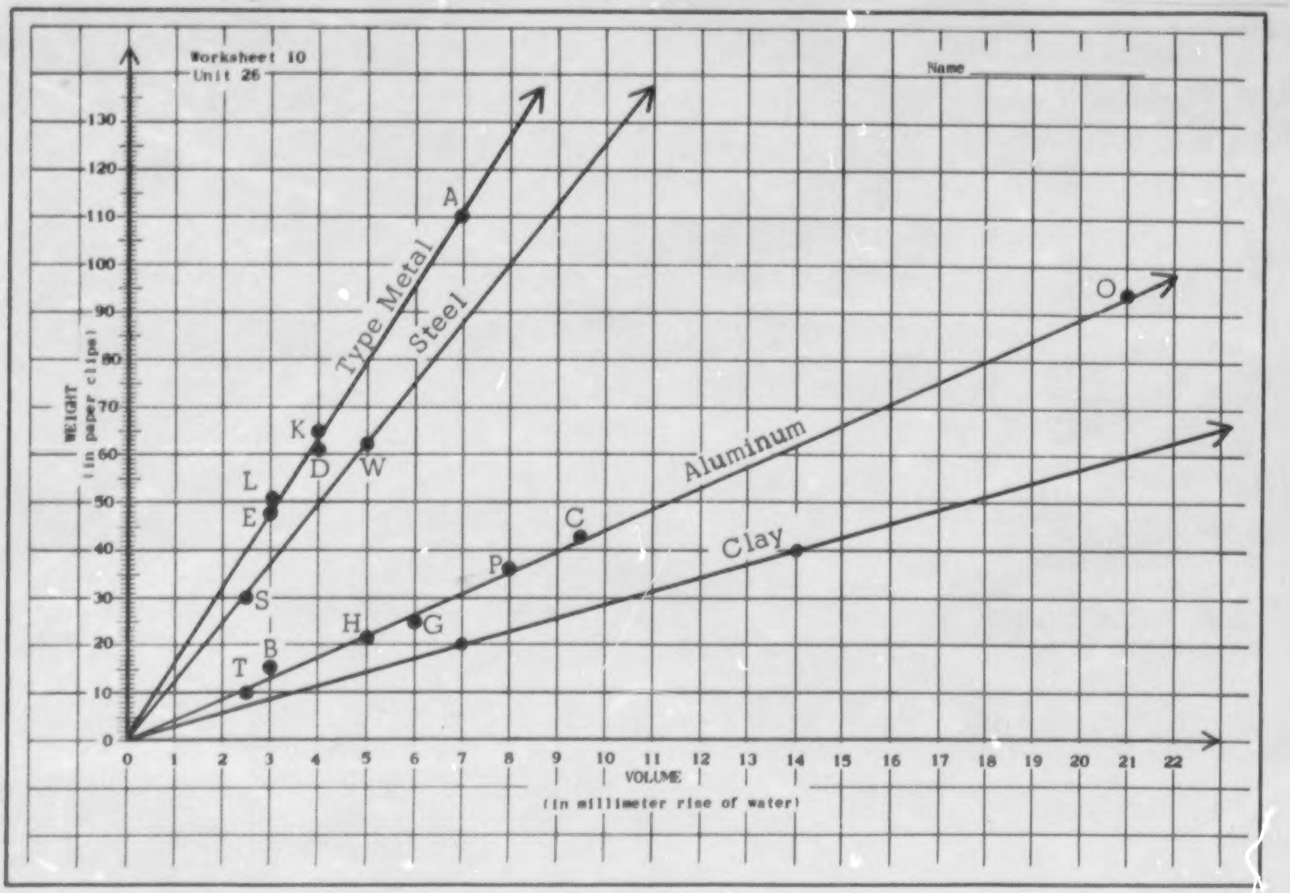
Worksheet 11
Unit 26

Name ______________

Metal Piece	Volume (in millimeter rise of water)	Weight (in paper clips)	Ordered Pairs V , W
A	7	110	(7 , 110)
B	3	15	(3 , 15)
D	4	61	(4 , 61)
G	6	25	(6 , 25)
K	4	65	(4 , 65)
L	3	50	(3 , 50)
P	8	36	(8 , 36)

When all the groups have finished, discuss their results. The points for A, D, K and L should fall on or near the same line as E. Tell the children that these pieces are made of metal used in printing and in typewriters and are called "type metal." Ask them to label this line accordingly.

Points B, G and P should fall on or near the aluminum line. (The placement of all metal pieces should also be checked by the hardness test.)



Tell the class that in the next lesson they will be reading a story about a man named Archimedes who used volume/weight relations to solve an important problem.

Save all copies of Worksheet 10 for use in Lesson 9.

Lesson 9: USING THE PROPERTY OF DENSITY

In this lesson the children use their knowledge of volume/weight relations to solve a problem. They see the usefulness of density as one way of testing materials to find out more about them. They also learn to identify density with the slope of a line on a volume/weight graph.

The name "density" is given to the volume/weight relations the children have been studying in this section. (More precisely, density is defined as the mass per unit volume rather than the weight per unit volume, or as the slope of a mass/volume line rather than a weight/volume line. Mass is the amount of substance or material in an object, whereas weight is the gravitational force or pull the earth or other large body exerts on the object. An astronaut's mass, for example, is nearly always the same but he has no weight in orbit and only one-sixth of his earth weight on the moon. On the surface of the earth, weight and mass are always proportional, so either one may be measured to determine the other. Since weight is easier to measure and easier for children to understand, weight rather than mass was chosen for the work with density at this level.)

The children observe that, for a given unit of volume, the weight of a denser material will be greater than that of a less dense material. By looking at the slopes of the volume/weight graphs for two different materials, the children should be able to compare their densities. That is, they should see that the greater the slope of the volume/weight graph, the greater the density of the material.

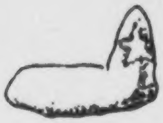
MATERIALS

- story, "Archimedes and the Crown," provided on pp. 75 - 89 of this lesson, and in the Student Manuals
- 2 balls of equal weight, 1 made entirely of clay and 1 with cork hidden inside the clay
- 1 set of volume and weight measurement equipment

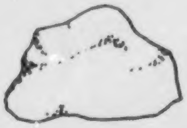
- 2 straightened paper clips
- Worksheets 10 and 12

PREPARATION

Before class, mold a ball of clay and a clay "crown" that weigh the same amount. The clay "crown" should have a small cork hidden inside of it, so that it will displace more water than the ball of pure clay.



Clay crown with cork hidden in it



Ball of clay

The ball of clay and the clay "crown" should be small enough to fit in the water-displacement cylinder. They can be deformed for this purpose, but be sure the children do not see the cork inside the crown.

PROCEDURE

Activity A

Have the children open their manuals to the beginning of the story, "Archimedes and the Crown." Read the story with the children following along, until you come to the question, "Can you figure out how Archimedes solved the problem?" At this point, have the children close their manuals, and gather around the demonstration table. Show the class the ball of clay and the clay crown. Tell the children that the ball of clay represents the chunk of gold in the story, and the clay crown represents the crown the goldsmith made. Then ask:

WHAT PROPERTIES DID THE CHUNK OF GOLD AND THE CROWN HAVE IN COMMON? (They looked as though they were both of the same material, and they weighed the same.)

Have a child check the ball of clay and the clay crown to see if they weigh the same. (They should balance each other.) Ask:

WHAT IS THE PROBLEM ARCHIMEDES HAS TO SOLVE? (He has to find out if the crown is made of pure gold.)

HOW CAN HE DO THIS? HOW MIGHT WE FIND OUT IF THIS CLAY CROWN IS MADE OF PURE CLAY?

Let the children think about this. Someone will probably remember from the last few lessons that, for the same kind of material, if the weights are the same the volumes should be the same. Maybe that is the thought that occurred to Archimedes as he lowered himself into the tub and saw the water rise. Let the children test this hypothesis by measuring the volume of the ball of clay and the clay crown. (The clay crown should displace more water than the clay ball.)

Ask the class if the volume/weight ordered pair for the clay crown would fall on the clay line on Worksheet 10. Have one child measure the weight and volume for the crown, and another child do the same for the ball of clay. Put these ordered pairs on the chalkboard and ask the children to plot the points on their worksheets. The point for the crown will not fall on the clay line -- it will be located somewhere below the clay line. The children should now see that the clay crown is not pure clay. They should check this by breaking the crown apart and finding the cork. Now finish reading the story to the children.

Ask the children why Archimedes used neither the scratch test for hardness nor the breaking process on the golden crown. Couldn't he have found out whether or not the crown was made of pure gold more quickly if he used these tests? (Maybe, but it would have ruined the crown to scratch or break it, and if it had turned out to be made of pure gold after all he would have been in trouble.)

Tell the children that the volume/weight relations that they have been studying indicate a property that is known as density. Have them turn to Worksheet 10. Tell them that the slope of the clay line represents the density of clay and that the slope of the aluminum line represents the density of aluminum. Do this for all the lines the children have graphed, finishing with the density of type metal. Explain that one can describe some materials as denser than others. Remind them of their experiences with the cubes of similar size, S and T, and how they observed at that time that "some materials seem to be heavier for their size than others." Ask how they could now put this observation into other terms, e.g., "S is made of a denser material than T is." Then say:

> LOOKING AT ALL THE LINES YOU HAVE GRAPHED ON WORKSHEET 10, WHICH MATERIAL DO YOU THINK IS DENSEST OF ALL? (Type metal.) WHY?

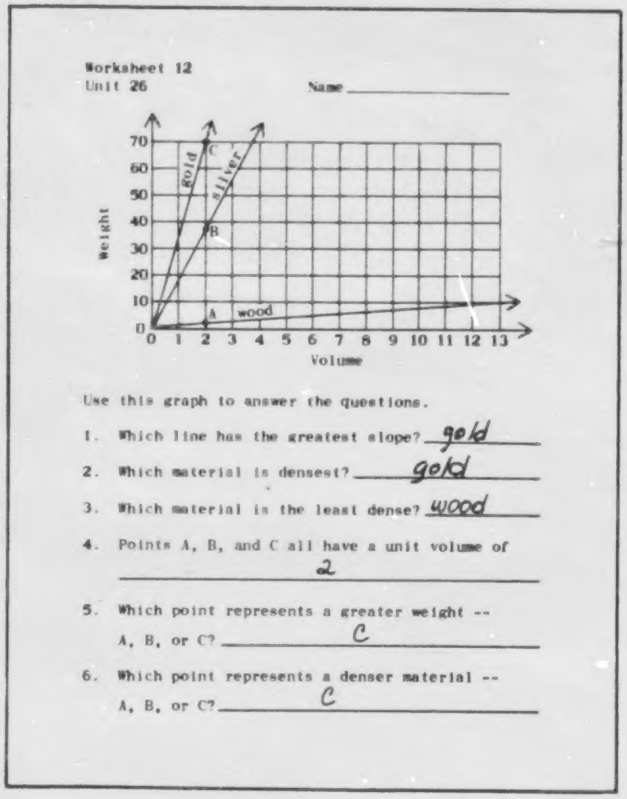
Let the children think about and discuss the reasons. Then bring into the discussion the following ideas:

1. For a given volume, type metal is the heaviest of all the materials studied. Steel is heavier than aluminum or clay for the same volume -- therefore steel is denser than either aluminum or clay, but less dense than type metal. Discuss similar examples with the class, including such questions as: "Which material is the least dense?" (Clay.) Which materials are denser than aluminum? (Steel and type metal.) Which material is not as dense as aluminum? (Clay.) Is the density of the clay crown greater or less than the density of the clay ball? (Less.)

2. The denser the material, the greater the slope of its volume/weight graph. Have the children give examples of this, by showing that the slope of the type metal density line is greater than the slope of other density lines, etc. An analogy can be made to the slope concepts used in Unit 25, where on time/distance graphs of the motion of cars, the children saw that the greater the slope, the greater the speed it represents.

3. Being able to figure out the density of a material (the relation between its volume and weight) is a valuable test in helping to distinguish one material from another. It is especially useful because the object to be tested does not have to be mutilated in any way (unless it happens to be soluble in water).

Have the children do Worksheet 12.



Worksheet 12
Unit 26

Name ____________

70
60
50
40
30
20
10
0
Weight
gold
silver
wood
A
B
C
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Volume

Use this graph to answer the questions.

1. Which line has the greatest slope? gold

2. Which material is densest? gold

3. Which material is the least dense? wood

4. Points A, B, and C all have a unit volume of 2

5. Which point represents a greater weight -- A, B, or C? C

6. Which point represents a denser material -- A, B, or C? C

Ask the children to bring in from home any small objects they want to test for density. The only qualifications are that the objects will not melt in water and will fit in the water displacement cylinder.

In the next lesson the children will have an opportunity to test everyday objects for the property of density. They will use small objects in the classroom as well as appropriate items brought from home.

ARCHIMEDES and the CROWN

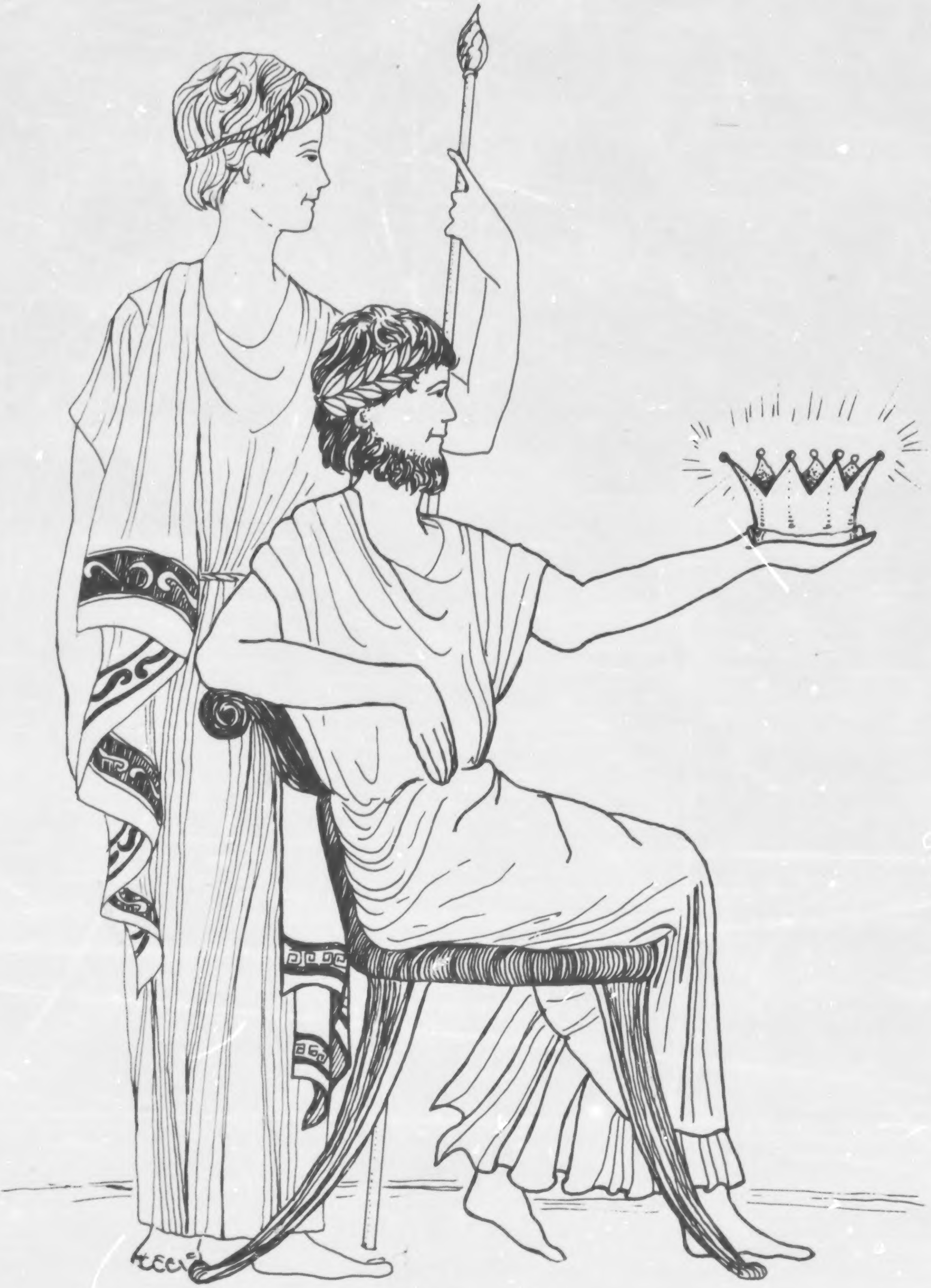
Archimedes and the Crown

Long ago, one of the largest and richest cities in the whole world was Syracuse. It was a Greek city. In those days a city had its own king. The king of Syracuse was named Hieron (HIE-uh-ron).

The Greeks at that time had a religion that was different from any of yours. They worshipped many gods. They used to go to the temples and leave gifts for the gods. This is a story about one of those gifts.

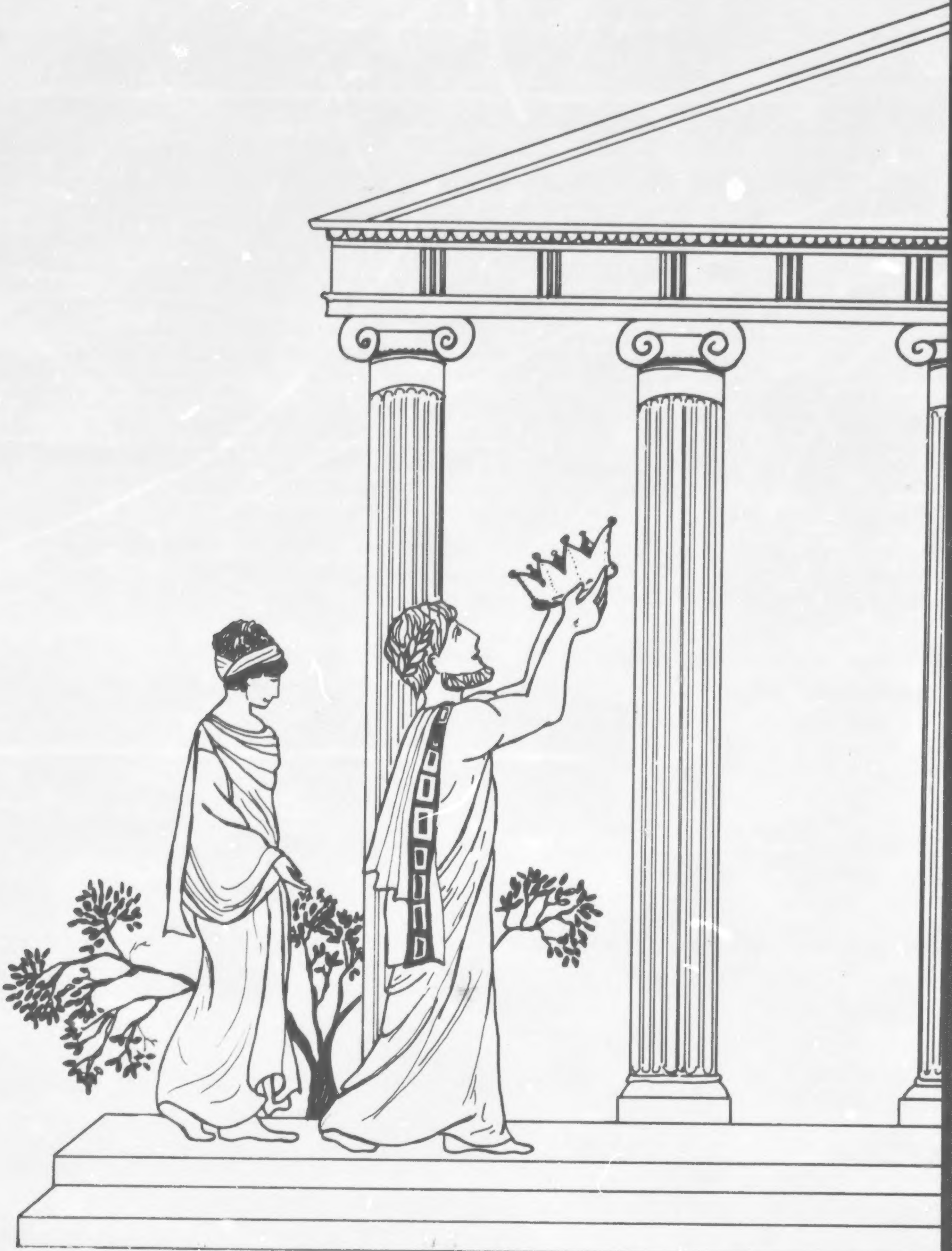
The people of Syracuse had lived a long time without troubles. They thought that this was because the gods were pleased with them. So Hieron, the king, decided to give an especially beautiful gift to the gods, as a way of saying, "Thank you."

He sent a heavy chunk of gold to the city's best goldsmith, and asked him to make it into a crown for the gods. One thing you should know -- Hieron weighed the gold before he gave it to the goldsmith, to be sure that it would all be used for the crown.



The goldsmith worked long and hard. When he was finished everyone agreed that he had made the most beautiful crown they had ever seen.

Hieron thought it was beautiful too, but there was something else he wanted to know. Had the goldsmith kept any of the gold, or had he put it all into the crown? So Hieron weighed the crown, and he found that it weighed just as much as the chunk of gold he had given the goldsmith. He was satisfied, and the crown was taken to the temple. There was a great ceremony and the crown was laid on the altar.



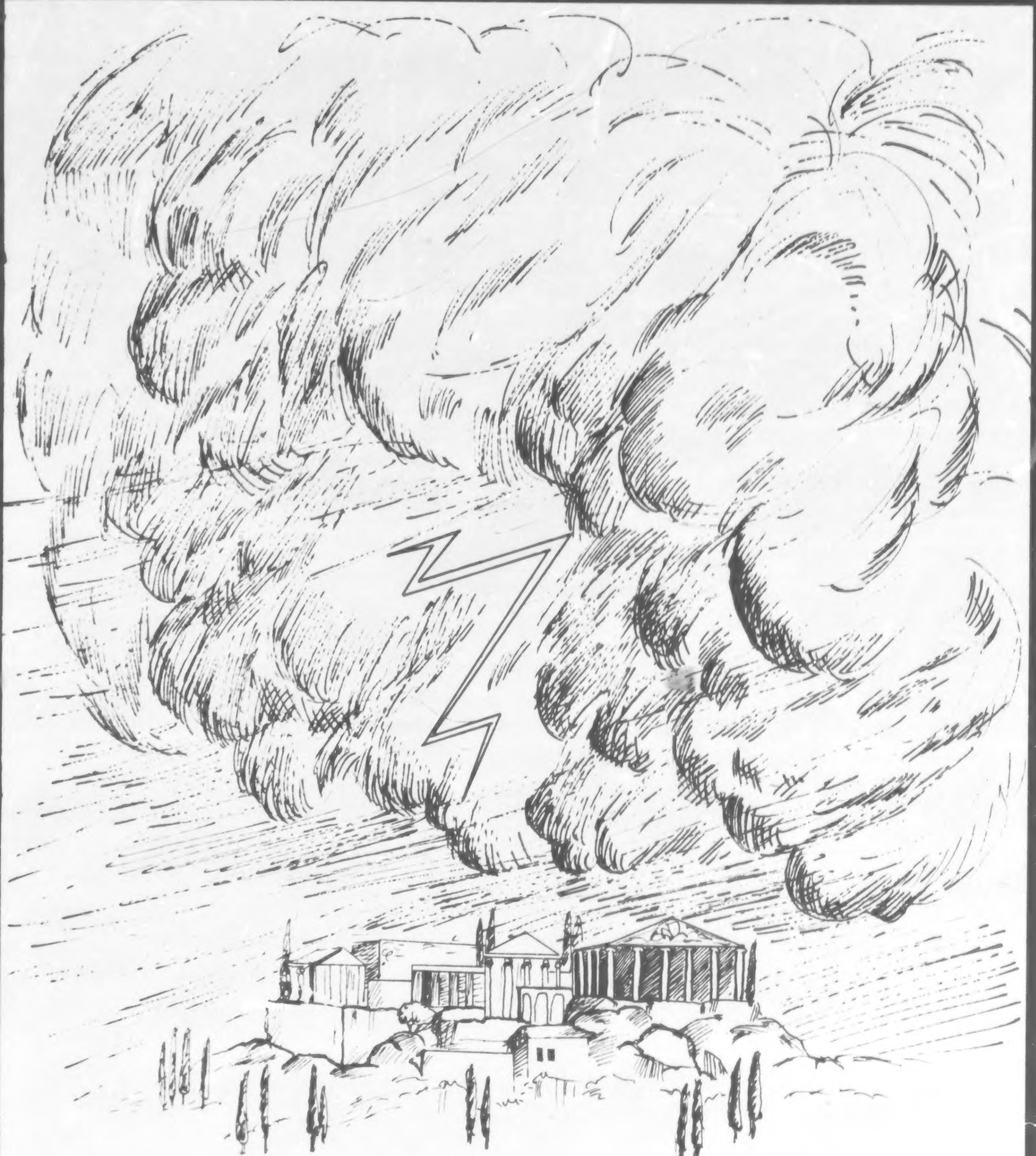
At that moment there was a crash of thunder. A terrible storm came up, and it stormed for three days and three nights. And then, when the storm was over, the weather did not get bright and clear again. It stayed gray and gloomy for a long, long time.

So the people began whispering to each other, "The gods are angry." They believed that the gods decided every little thing that happened to people. Whenever bad things happened, they said the gods were angry, and whenever good things happened they said the gods were pleased.

As the storm raged, and as the gloom went on, wherever people met they said the same thing, "The gods are angry."

In Syracuse when people wanted water they went to a public well. And when they met there to draw water, they whispered, "Why do you think the gods are angry?"

When people wanted to bathe or swim they went to a special building, the public baths. And when they met there, they whispered, "The gods are angry because the crown that Hieron gave them wasn't pure gold."

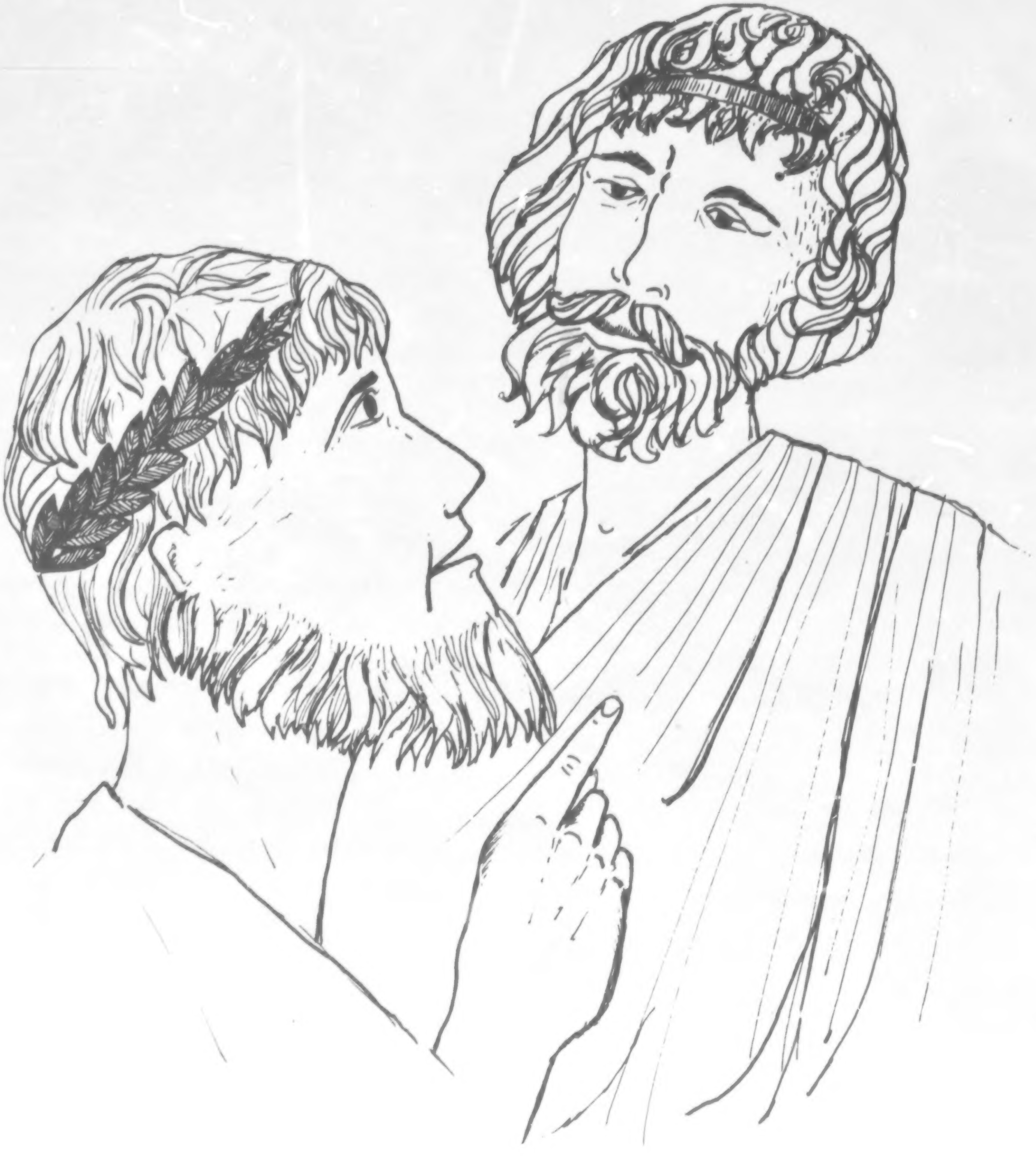


You can be sure that it didn't take long for Hieron to hear what the people were saying. He was very worried, because of course he wanted the gods to be pleased so that they would continue to give the people of Syracuse good luck.

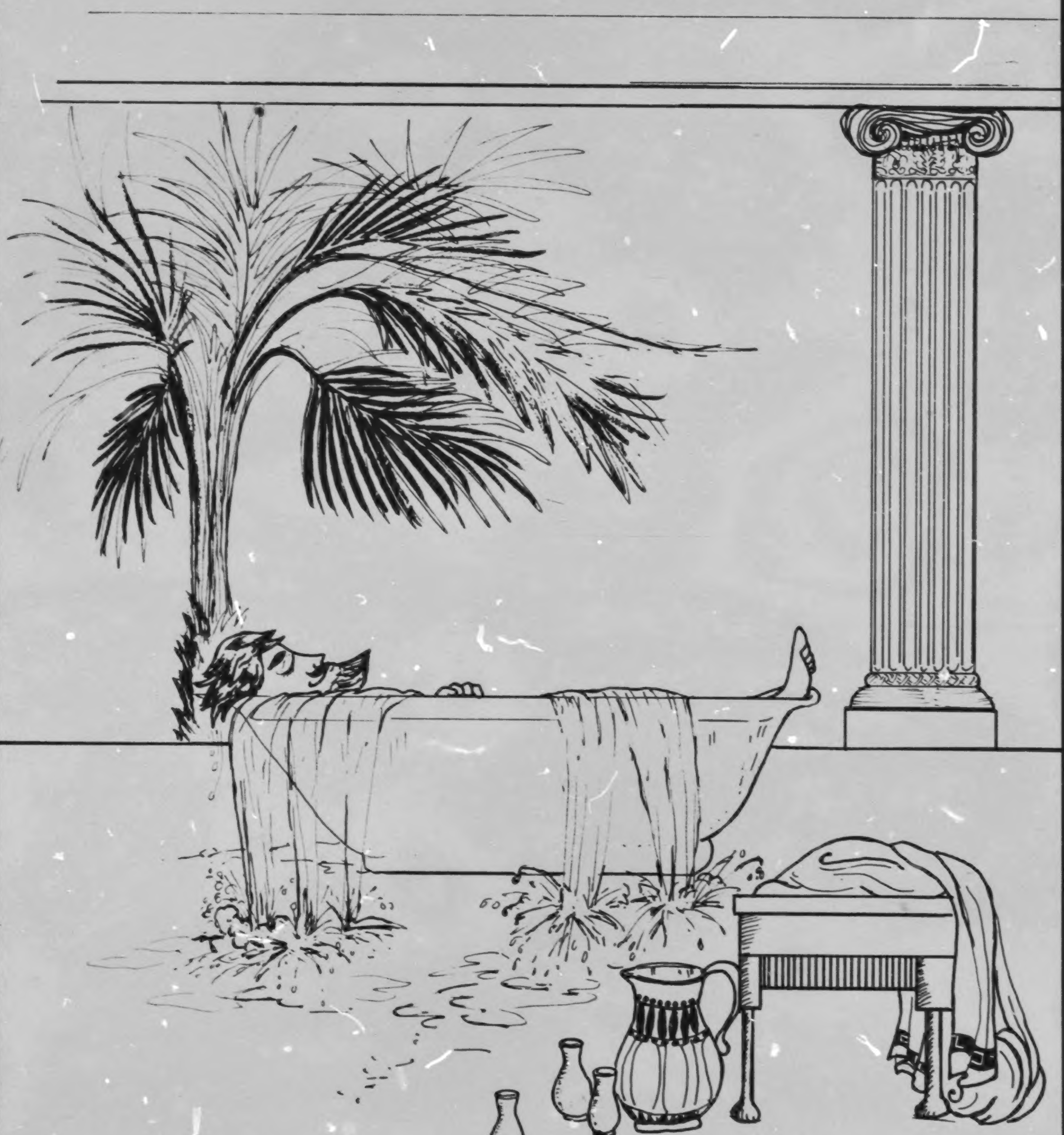
But what could he do? He had weighed the crown, and had found that it weighed just as much as the chunk of gold he had given the goldsmith. What more could he do?

He called in one of the city's wisest men, Archimedes (ARK-uh-ME-dees). He asked Archimedes if he knew how to tell whether or not the crown was pure gold.

Archimedes did not know any test that would tell. But he was wise enough to know that he didn't know everything. If he didn't know a test, it didn't mean that there wasn't any. So he thought and thought for many days and nights. The problem was on his mind when he ate and when he walked and even when he slept.

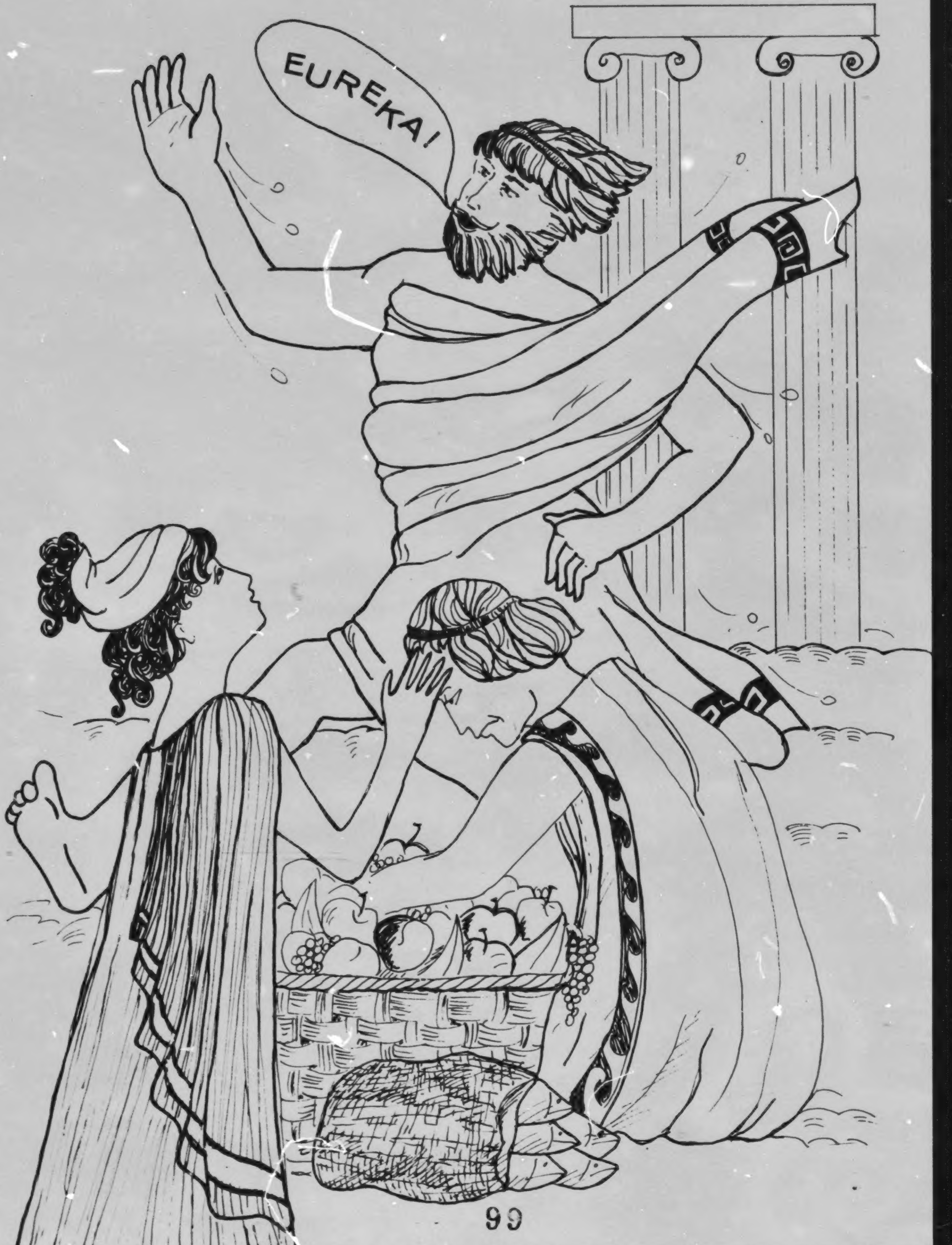


One afternoon he went out to the public baths. He walked down the street and looked up at the gray sky and shook his head sadly. The gods were still angry. He stepped into a very full bathtub and let himself down slowly. He watched the water go higher and higher in the tub as he went lower and lower into it. By the time all of him except his head was under the water, the water had spilled out over the top. He lay there in a sort of dreamy way, watching the ripples on the surface of the water.



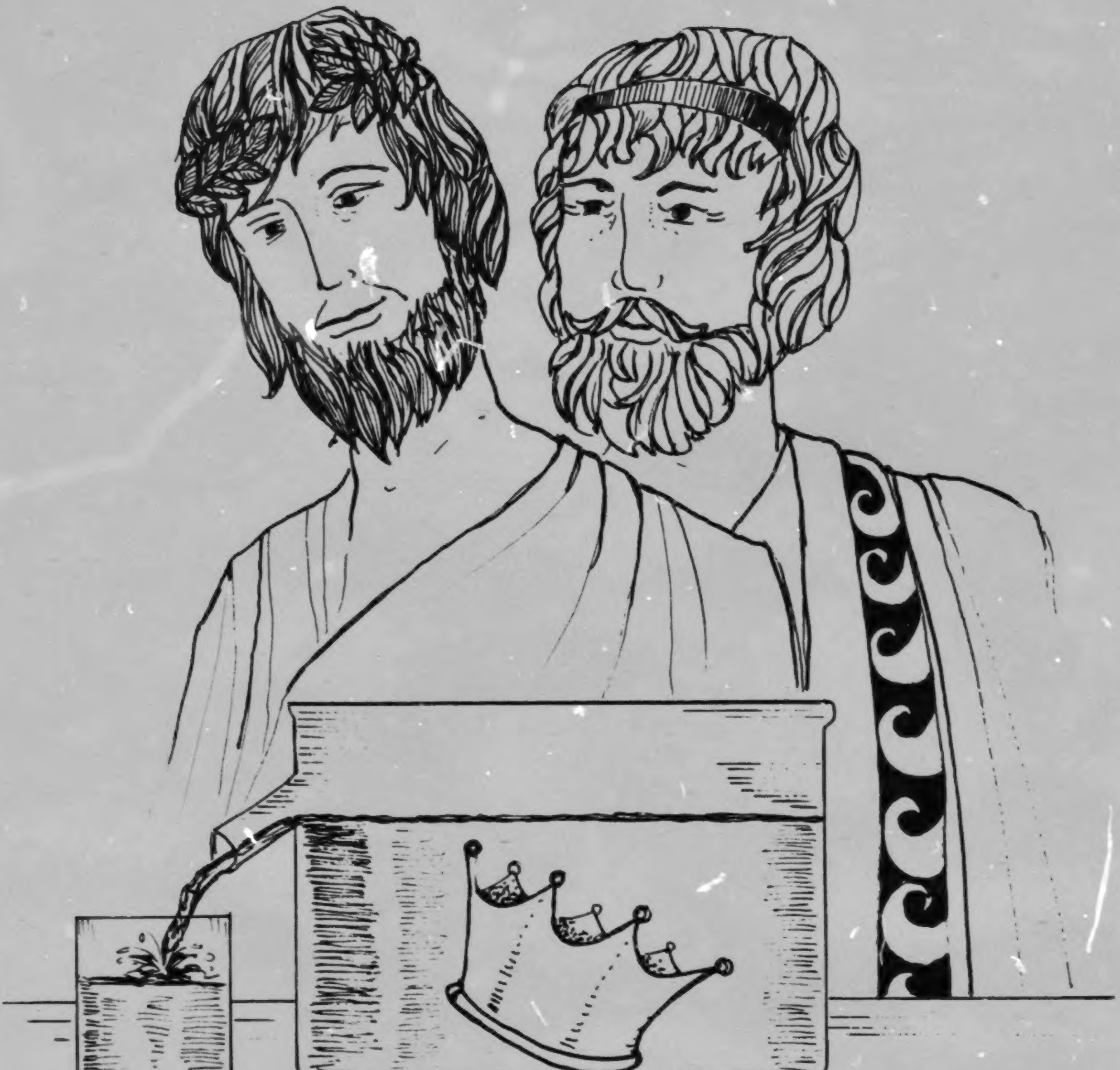
Suddenly he jumped up with a great splash. "Eureka," he shouted. (In Greek that means "I have found it!") He never even stopped for his clothes, but ran out of the bathhouse and through the streets of Syracuse shouting, "Eureka, Eureka!"

What do you think he had found? Of course -- he knew how to find out if the crown was pure gold. Can you figure out how Archimedes solved the problem?


EUREKA!

He took a container that had a spout at the side. He filled it with water just up to the opening of the spout. Then he lowered into the water a chunk of pure gold that weighed just as much as the crown. When he put the gold into the water, the water rose and ran out the spout. He measured how much water was displaced by the gold chunk. Then he refilled the container and did the same thing with a chunk of silver that weighed just as much as the crown. He measured the amount of water that the silver displaced. And last of all, he put the crown itself under water and measured the amount of water _it_ displaced.

Archimedes compared the three amounts of water, and then he said, "The goldsmith cheated you, Hieron. The crown is not pure gold."



Lesson 10: INVESTIGATING THE DENSITY OF OTHER MATERIALS

The purposes of the lesson are: (1) to have the children use the property of density as a test of what a material may or may not be; (2) to reemphasize the fact that testing for only one property is not adequate for identifying a material; and (3) to have the children apply such scientific processes as observing, formulating hypotheses, and gathering and graphing data to test the hypotheses.

The children are given opportunities in this lesson to use the property of density to investigate the materials of which some small common objects are composed. They should test several such objects brought from home, as well as some found in the classroom. There are only two limitations on what objects can be tested: (1) the objects should not be soluble in water and (2) they should be small enough to be measured in the water displacement cylinder. Some appropriate objects are:

pencil stubs
crayons
rubber erasers
coins
beads
glass
keys
very small metal toys
rocks or pebbles
buttons
nails or screws
Minnebars
vegetables (piece of raw potato, small carrot, etc.)

If very small objects, such as paper clips or safety pins are used, several identical objects can be taped or tied together to provide a larger sample of the material.

MATERIALS

-- for the demonstration (Activity A) --

- 1 penlight battery
- scissors
- 1 piece each of aluminum, type metal and steel (from previous lessons)

- hammer
- thick padding of newspaper or small board on which to break battery

-- for each group of four --

- 1 penlight battery
- volume and weight measuring equipment
- several small objects to measure for density

-- for each child --

- Worksheets 13 through 19
- scissors

Activity A

Organize the class into groups of four. Give each group one penlight battery. Then ask:

> OF WHAT MATERIAL DO YOU THINK THE BATTERIES ARE MADE?

Let the children speculate. Then ask a child to scrape some of the paint from the side of the battery with scissors. Have him show the class that there seems to be metal under the paint. Then say:

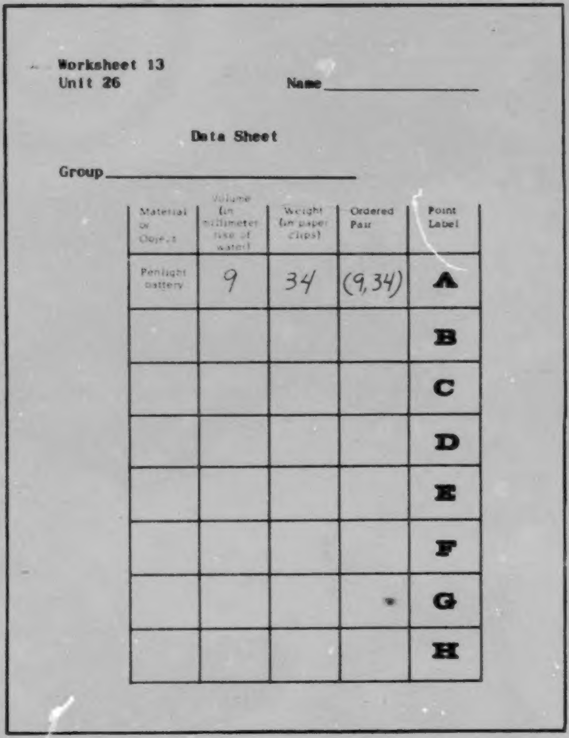
> THE BATTERIES SEEM TO BE MADE OF SOME KIND OF METAL. WHAT PROPERTY MIGHT WE TEST? (Hardness.)

Have volunteers test the hardness of the batteries with the hardness of metal samples of aluminum, type metal and steel. (They will find out that the battery will scratch type metal and aluminum, but not steel.) State the result:

> IT APPEARS THAT THE HARDNESS OF THE BATTERY IS SIMILAR TO THAT OF STEEL.

Then ask if there is another property that the children could test. They should think of testing the density. Follow this up by suggesting that perhaps the children would like to find out whether or not the battery material is as dense as steel.

Have each group come and get their volume and weight measuring equipment, and ask them to measure the volume and weight of the batteries you have already given them. When all the groups have done this, ask for the data from each group. Errors should be corrected at this time, and a reasonable set of measurements agreed upon for the ordered pair: (9, 34). Each child should record the name of the object and the ordered pair on Worksheet 13 on the line marked "A".



Worksheet 13
Unit 26

Name ____________

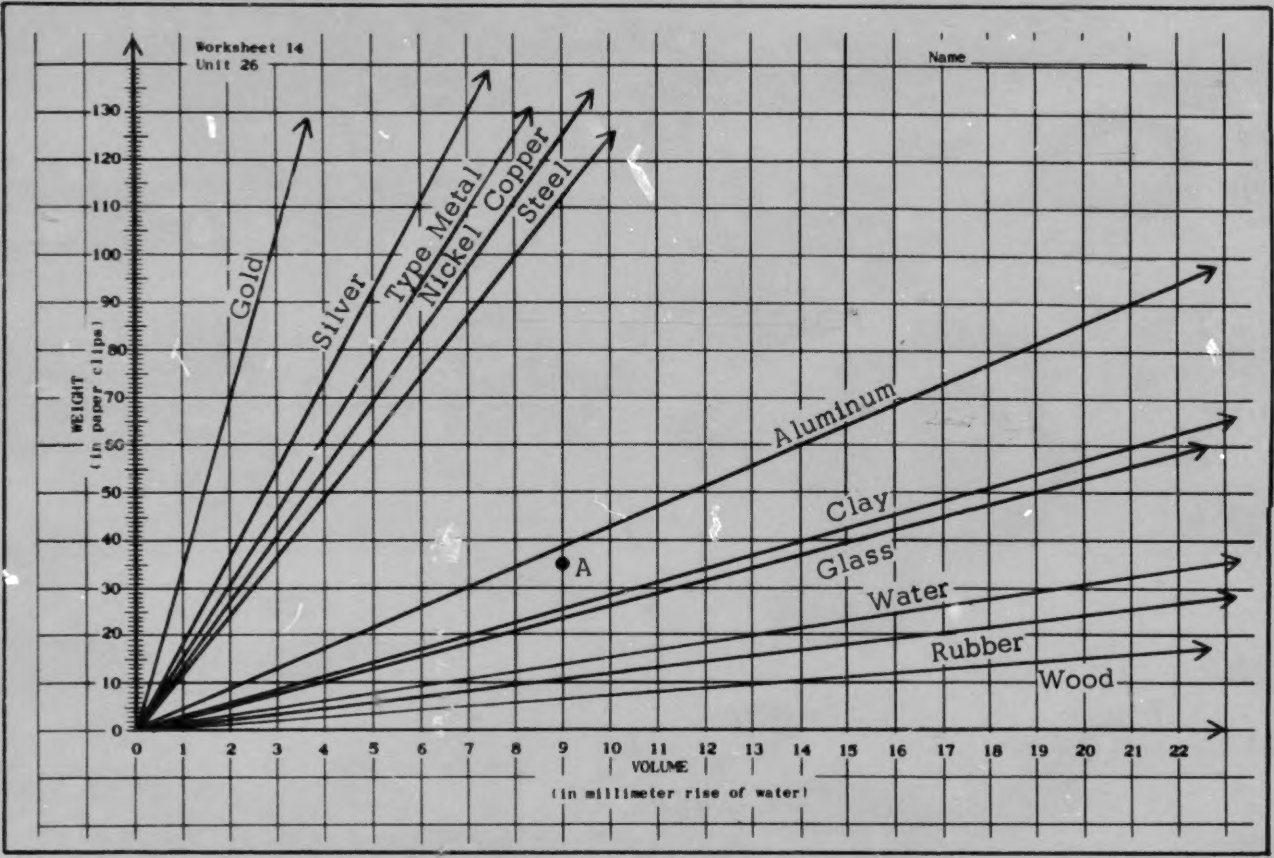
Data Sheet

Group ____________________

Material or Object	Volume (in milliliter rise of water)	Weight (in paper clips)	Ordered Pair	Point Label
Penlight battery	9	34	(9,34)	**A**
				B
				C
				D
				E
				F
				G
				H

Next ask how the densities of the battery and of steel could be compared. (By plotting the volume/weight ordered pairs for each material on the same grid.) Some child may notice that Worksheet 14 already has graphs representing the density of steel and of some other materials. Call attention to this and say that all the class really needs to do is plot the ordered pair that they have agreed upon as representing the density of the battery (9, 34) on Worksheet 14. Each child should do this. He should label this point "A" to agree with Worksheet 13.

When the children have labeled the point that represents the density of the batteries, ask whether the battery material is as dense as steel.



The children will see that the battery's density is less than steel and even less than that of aluminum. Discuss with the class [illegible] this could mean:

1. Since the battery's density is so much less than steel, it probably is not steel.

2. Since it seems to be less dense than aluminum -- and yet it is harder than aluminum -- it is probably not aluminum either.

Ask:

> DOES THIS MEAN THAT THERE IS ABSOLUTELY NO STEEL OR ALUMINUM IN THIS BATTERY? (No. The battery may be made of more than one material, including some steel or aluminum. It probably is not pure steel or aluminum.)
>
> HOW CAN WE FIND OUT IF THIS BATTERY IS MADE OF SEVERAL MATERIALS? (We could run further tests on it. The most obvious and easiest test would be to take the battery apart.)

Tell the class that instead of ruining all the batteries, only one will be taken apart. Place thick newspaper or a board on the floor. Place the battery on a sheet of white paper and use the hammer to break it open. To do this most easily, pound along the seam of the battery. When broken, the different materials of which the battery is composed will be revealed. Black powder will spill out and pieces of a hard carbon rod that was the center core of the battery will be seen. It is best to use a stick or pencil when examining the carbon, as it contains paste and therefore clings to fingers and clothing. When you have shaken out all of the carbon, there will still be visible a cardboard liner inside of the metal which is zinc.

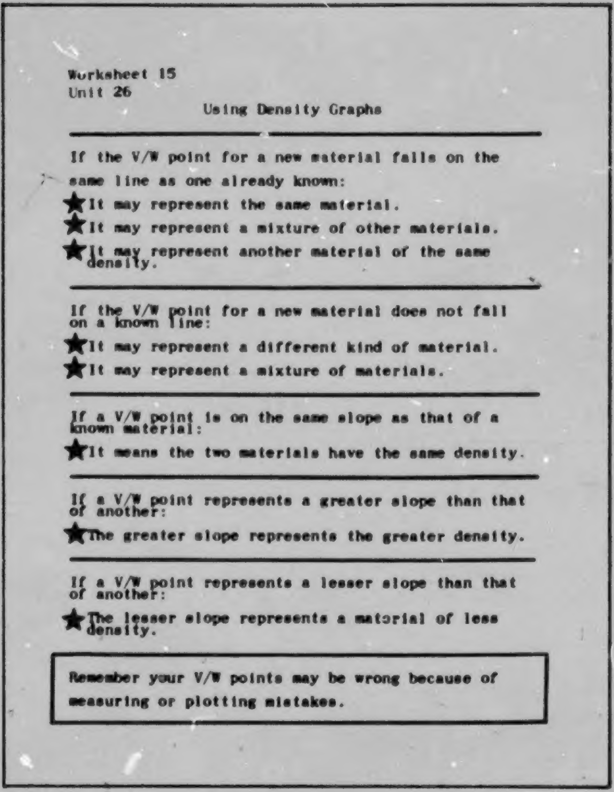
Pass the smashed battery around so the class can see that it is indeed composed of several materials. Ask the children to name some of them. They might mention: paint, metal, soft carbon powder, hard carbon core, acid and cardboard.

Discuss with the class how one might find out what the outer metal of the battery is. The children should see that if they could separate the outer metal from the other materials, perhaps they could get some indication of what kind of metal it is by using the hardness and density tests. Some child or group of children may want to do this. However, they may have some difficulty in separating the metal from the materials, so they should do this on their own free time.

Ask the children how they could use the graphs on Worksheet 14 to help them identify other materials of which objects are made. The class should, by now, be able to say that measuring the volume and weight of an object, plotting the ordered pair on the grid, and comparing the location of this point with the known density lines, ought to tell them a good deal about the density of the new material. Add to this the fact that when the children know about an object's density, they can use this as a guide for further investigations. Remind them that, although the exterior of the battery suggested that the object was made of a material like steel or aluminum, its density measurement revealed that it was either another kind of material altogether, or a combination of several. Density was a very good clue.

Have the groups of children measure the volume and weight of several objects they have brought or that they can find in the classroom. Groups may exchange materials after they have used them. The data for each object should be recorded on Worksheet 13 and graphed on Worksheet 14 by each child. Each point they put on the graph should be labeled with a letter of the alphabet, just as A indicates the density of the battery.

When each child in the group has graphed the data on his worksheet, the group should discuss the implications among themselves. They can use Worksheet 15 as a guide for these discussions. When all groups have finished their discussions, each should appoint a spokesman to report their findings to the class in the next activity.



Worksheet 15
Unit 26

Using Density Graphs

If the V/W point for a new material falls on the same line as one already known:

★It may represent the same material.
★It may represent a mixture of other materials.
★It may represent another material of the same density.

If the V/W point for a new material does not fall on a known line:

★It may represent a different kind of material.
★It may represent a mixture of materials.

If a V/W point is on the same slope as that of a known material:

★It means the two materials have the same density.

If a V/W point represents a greater slope than that of another:

★The greater slope represents the greater density.

If a V/W point represents a lesser slope than that of another:

★The lesser slope represents a material of less density.

Remember your V/W points may be wrong because of measuring or plotting mistakes.

Activity B

Have the class gather around a demonstration table. Ask the spokesman from each group to report his group's findings in a show-and-tell fashion. The spokesman should show where the point that represents the density of an object fell on the grid and discuss the implications. If another group has used the same object, that spokesman should compare and discuss his group's results. The children should feel free to challenge a hypothesis and to offer alternate ones.

End this activity with a discussion of Worksheet 15. Tell the children that they will be able to use their knowledge of volume/weight relations to play a game in the next activity. They will be needing Worksheet 14, so they should save it.

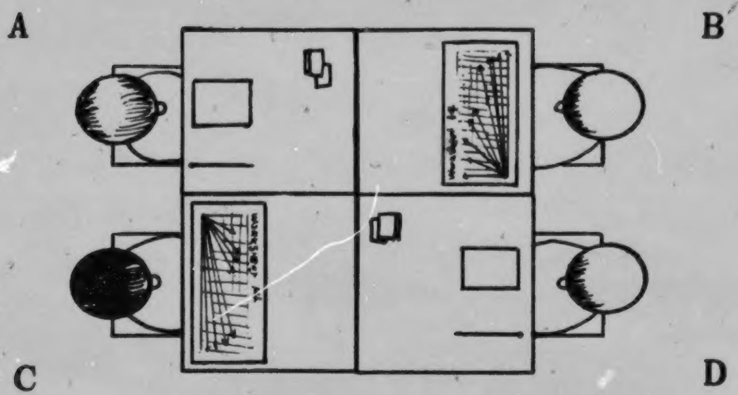
Activity C

The purpose of this game is to reinforce the learnings that have taken place in this section on density. The children use the graph on Worksheet 14 to answer questions about density.

Ask them to remove Worksheets 14, 16, 17 and 18 from their Student Manuals. Have them cut Worksheets 16, 17 and 18 into eight cards each, so that every card has a different question on it. When finished, each child should have a deck of 24 question cards. Have the children turn the cards over and mark each one with their initials. Then provide paper clips so that each child can keep his deck together.

Have the children choose partners. As a demonstration, have two pairs of children show the procedure for the game described below.

Each pair needs only one deck of question cards for this game. (The extra sets should be put away for later use.) Each pair also needs a sheet of paper on which to keep score and a copy of Worksheet 14. Arrange the desks so that one pair of children faces another, as shown here.



Worksheet 16
Unit 26

This material is denser than glass, but it is not a metal. What might it be? clay	For a volume of 4, which material weighs the most? gold
Which material graphed on Worksheet 14 is most dense? gold	For any given volume, which material will weigh the most? gold, or the densest
You have gold that weighs 40 paper clips and aluminum that weighs 40 paper clips. Which has the greater volume? aluminum	You have a lump of nickel and a lump of silver, each weighing 30 paper clips. Which material has the greater volume? nickel
If someone says, "Glass is not as dense as clay," is that true or false? True	Which is denser, wood or water? water

Worksheet 17
Unit 26

If the slope of Line A is greater than the slope of Line B, which line would represent a denser material, A or B? line A	Which density line has the steepest slope on this grid? gold
Which density line has the smallest slope on Worksheet 14? wood	If rock is denser than wood, which would have the steeper slope? rock
Water is less dense than type metal. Which density line is less steep? water	You have a piece of gold and a piece of silver that weigh the same. Which has the greater volume? silver
You have two pieces of material that are the same size. One is copper and one is rubber. Which piece weighs more? copper	You have two pieces of material that have the same volume. One is wood and the other is glass. Which piece weighs more. glass

Worksheet 18
Unit 26

Silver is denser than gold. Is this true or false? False	Which is denser, nickel or copper? They have the same density
For a volume of 3, which material weighs the most? gold	For a weight of 10 paper clips, which material has the greatest volume? wood
If you get the ordered pair (2,70) for a material, it is as dense as_________. gold	If you get the ordered pair (8,60) for a material, the material is denser than steel. Is this true or false? False
For a volume of 13, which weighs more -- water or wood? water	You have a piece of material that weighs 60 paper clips and has a volume of 4. What kind of material might it be? nickel or copper

Worksheet 19
Unit 26

Then give these instructions:

Step 1. Each pair should mix their cards thoroughly.

Step 2. Each deck of cards should be placed face down on a desk.

Step 3. Call one pair "A" and the other pair "B". Pair A turns up the top card from their own deck. They read the question to themselves and figure out the answer by referring to the graphs on Worksheet 14. At the same time, Pair B is doing the same thing with its own top card.

Step 4. Pair A and Pair B exchange the cards they just used.

Step 5. Pair A gives the answer to the question received from Pair B. If right, Pair A scores one point. If wrong, Pair B answers and scores the point, explaining why Pair A was incorrect. If Pair B cannot do this, Pair A has another chance to answer the question and score the point. If neither pair can answer the question, the card is placed at the bottom of the deck.

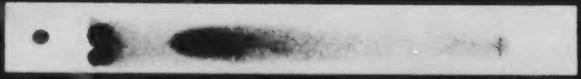
Step 6. Pair B now gives their answer to the question card that they received from Pair A. Each pair should put all answered questions in a separate pile.

Step 7. Repeat Steps 3 through 6.

When the game is over, the pair with the most points wins. If some questions cannot be answered by either pair, they should ask for your help.

Worksheet 19 can be used by the children to make up additional questions about density. Some children may enjoy playing the Density Game on a one-to-one basis.

COLOR SEPARATION



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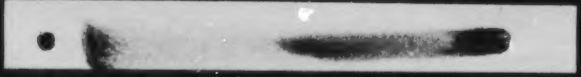

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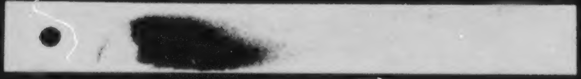

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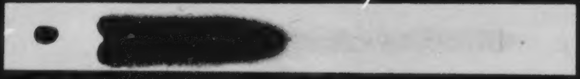

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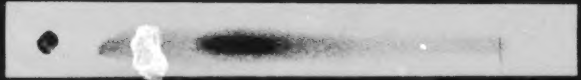


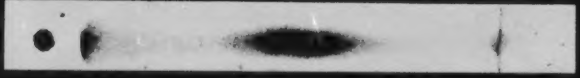
[illegible] Purple Thrifty Marker

Sanford Purple Felt Marker

Sheaffer Washable Peacock Blue Ink

Sheaffer Washable Blue Ink

Sanford Black Felt Marker



[illegible] Art Pen

Sanford Orange Felt Marker

Sanford Yellow Felt Marker

Bic Black Ball Point

SECTION 5 THE PROPERTY OF COLOR SEPARATION

PURPOSE

- To have the children find out whether or not certain colored liquids have any properties that would aid in distinguishing one from another.
- To have the children use the property of color separation for identifying their experimental colored liquids.

COMMENTARY

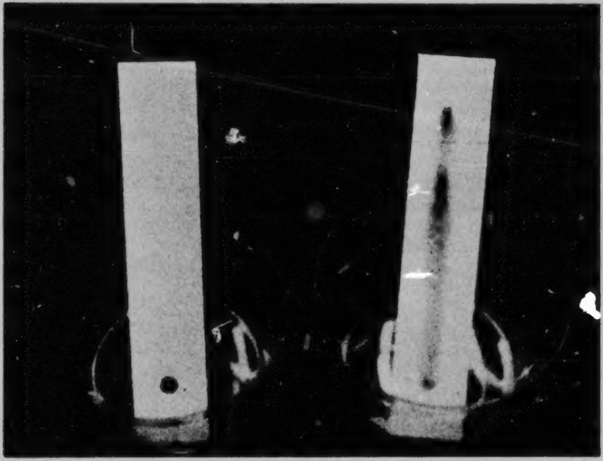
In the previous ten lessons the children have worked exclusively with solid materials that could be tested for properties of hardness and density. In this section, which consists of only one lesson, the children will find out that colored liquids also have an interesting property that can be used for identification. They will learn this by doing experiments with various inks and food colors and seeing how the colors separate.

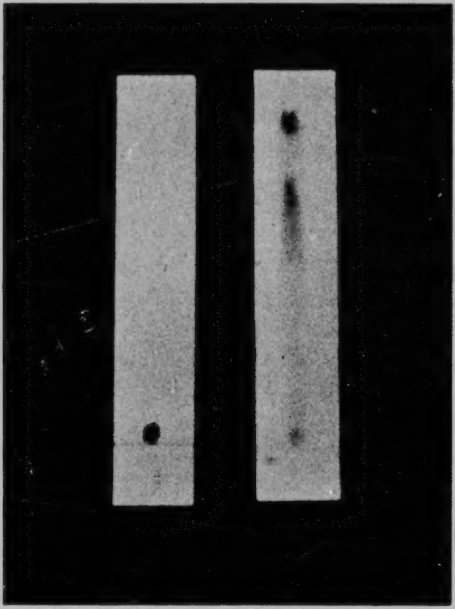
The method is this: about half an inch from the end of a strip of blotting paper, the children place a dot of ink (or of food coloring). The dotted end of the strip is then placed in a very small amount of water. The water rises in the blotter, separating the colors. The children discover that a black ink is made of a mixture of several different colors, and that a yellow food coloring may have some brown in it, a red food coloring may have had some yellow in it, etc.

The separations are very pretty and the children are fascinated by them. You may wish to ask them to bring in felt tip pens of colors other than those provided in the kit, or to test some that you happen to have in the classroom.

Teaching time for this section should be from one to two class periods.

NOTE: What the children do in this lesson is called "paper chromatography." The paper strip with the separated colors is called a "chromatogram" (literally, "color writing"). Chromatography works on the principle that molecules of different substances travel up the blotting paper at different speeds. The greater the attraction between the blotter and the molecules, the more slowly the molecules rise. If the children ask why the process works, you might wish to tell them that it depends on adsorption (sticking property); that some colors or materials are more easily retained by the surface of the paper than others.





Lesson 11: DISCOVERING A PROPERTY OF LIQUIDS

The purposes of this lesson are (1) to introduce the idea that some solutions have their own special color separation patterns and (2) to have the children identify colored solutions by comparing the patterns of color separation that each kind makes on a strip of blotting paper.

This lesson extends the color separation lessons that the children may have studied in Unit 15, Investigating Systems. Activity A shows the children a method of identifying inks through their color separation patterns. It involves placing a spot of ink on a piece of white blotter and allowing water to travel up to and beyond the spot.

In Activity B the children experiment with other inks and colorings that they bring from home or that you can provide in the classroom.

MATERIALS

-- for each child --

- pencil, ruler
- 4 white blotter strips for Activity A; 5 or 6 for Activity B
- 1 four-ounce plastic container with a little water in the bottom (not more than one-eighth inch deep)
- magnifier
- newspaper to protect desk

-- Activity A --

- 5 trays
- 5 cartridges of Sheaffer washable black ink
- 5 cartridges of Parker permanent blue-black ink
- 5 cartridges of Parker permanent black ink
- 5 blue felt tip pens

-- Activity B --

- 3 or 4 trays
- 5 red felt tip pens
- kit of Schilling food colorings
- any ball point, cartridge or felt tip pens other than those previously used. (The children may bring these, or you may have some in the classroom.)

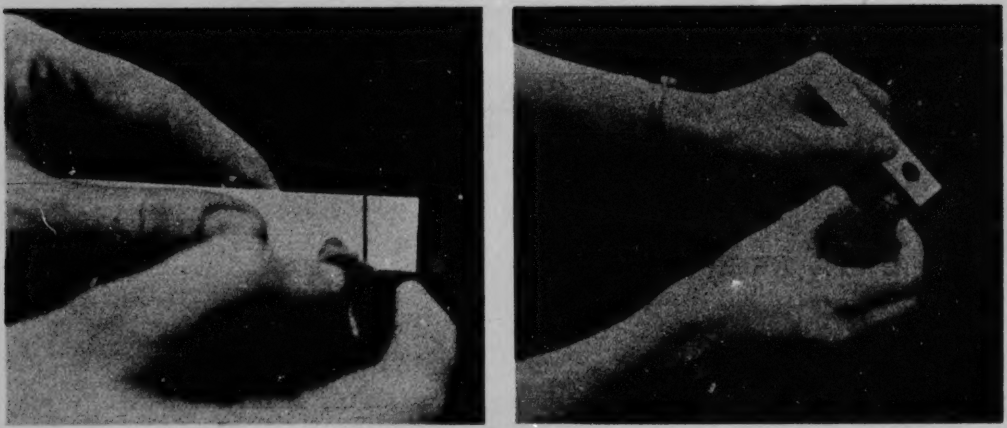
PREPARATION

The OMSI kit contains most of the items listed above. For Activity A, use trays to separate the various materials. For example, put all five Sheaffer washable black ink cartridges on one tray, all five Parker blue-black on another tray, etc. Make a hole in each cartridge with a pin, so that the children can get ink samples by pressing a blotter strip against a cartridge.

On a fifth tray, place one four-ounce plastic container for each child. Barely cover the bottom of each container with water. Be sure the water is not more than one-eighth inch deep. The children will be placing their ink spots about one-half inch above the bottom of their blotter strips, and the water will rise to the spots. If the water is too deep, spots will be immersed and some of the ink will go into the water, ruining the experiment.

The OMSI kit contains the white blotter strips the children will be using. Put a supply of these near the containers. Also have available some newspapers to protect desks and demonstration table.

For Activity B, put away all the inks and blue pens used in Activity A, and bring out the five red felt pens and the package of Schilling food colors. Put the red pens on one tray and the food colors on another. The children will again need blotter strips and a container with a little water in it.



Making a dot with food coloring from the kit

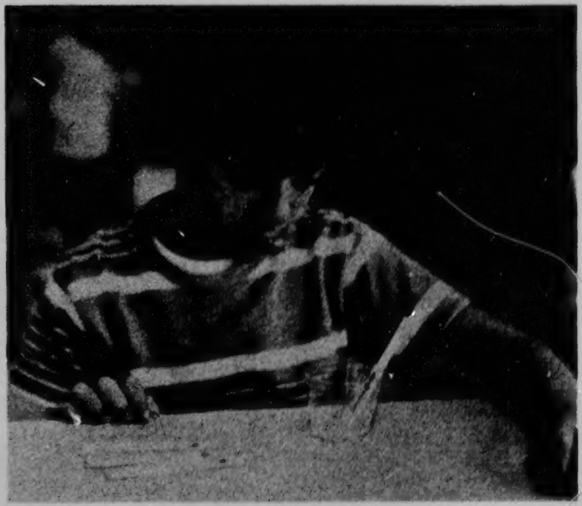
If you have been able to find pens with inks of any sort that have not already been used, make these available to the children. Also let them try out inks of other kinds that they have brought to class for that purpose.

It would be a good idea for you to do a few of the color separations in advance, so that you will know the technique. For example, practice making a small dot (about one-fourth inch in diameter) with the food colors so that you will be able to show the children how to hold the bottles when they wish to make a sample dot.

PROCEDURE

Activity A

Tell the children that they are going to have the opportunity to investigate the properties of several inks, but that first they need to prepare several blotter strips. Gather the class around the demonstration table. Tell the children that each child will prepare four blotter strips, and that each of his strips will have a spot of a different kind of ink. Show them the three different kinds of ink cartridges and the blue felt pen. With a pencil, draw a line one-half inch from one end of each of four blotter strips. Show the class how to make a spot of ink directly above the pencil line. Now make one spot on each of your four strips, using a different kind of ink for each strip. To do this with the cartridges, simply press the cartridge with the pin hole against the blotter at the place specified. With the felt pen, start to make the dot and then enlarge it with a circular motion until it is about one-fourth of an inch in diameter.



Give each child four blotter strips and have the class return to their desks. Instruct the children to draw a pencil line lightly one-half inch from one end of each blotter. Now separate the class into four groups. Give each group a tray that contains all five samples of a given ink, so that each of the four groups has a different ink. Each one in each group should take one of the five identical samples and make a dot on one blotter strip. When everyone in the group has made a dot with this particular ink, the tray of samples should be placed on one child's desk. When all the groups are finished, rotate the ink sets, so that each group now has a different kind of ink. Again, everyone makes one spot of the new ink on one blotter strip. The ink samples are then rotated again to another group until all the groups have used each ink type. Each child should end up with four blotter strips, each blotter having a spot made from a different kind of ink.

Now ask the children to hold up the blotter strip that has a spot that was made with Sheaffer ink. Hold up a Sheaffer cartridge to show what you mean. Responses may be quite interesting. Some children will probably hold up a strip without even hesitating. Others may have to think about it a while before choosing a strip to hold up. Still others may be unable to make any decision at all. In any case, ask those who responded quickly how they can be sure that the spots they held up were really made with Sheaffer ink. Then ask the other children why they can't make up their minds about which spot to hold up. In the ensuing discussion, bring out the following facts about the properties of the inks:

1. All the inks were absorbed by the blotting paper.
2. All the ink spots smell and feel the same.
3. From a little distance, all the ink spots appear to be about the same color.

Some children may say that a couple of the spots seem to be a little more blue than the others. This raises the possibility that maybe the inks are not exactly the same color -- maybe different colors were used to make these inks. Ask the children:

> HOW CAN WE FIND OUT WHETHER OR NOT THESE INKS ARE OF EXACTLY THE SAME COLOR?

Some will suggest observing the ink spots very closely. Have the children examine each of the spots with a magnifier. They will probably be able to separate the two bluer spots from the black spots, but it is rather difficult to distinguish between the two blues and between the two blacks.

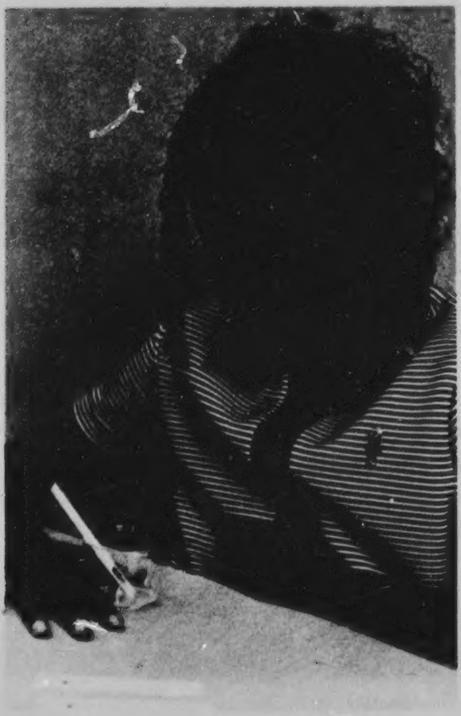
> CAN ANYONE THINK OF A TEST WE MIGHT MAKE ON THESE INKS THAT WOULD HELP US TO TELL ONE KIND OF INK FROM ANOTHER?

> CAN ANYONE THINK OF A TEST THAT WOULD TELL US WHETHER EACH INK IS A PURE COLOR OR A MIXTURE OF COLORS?

If no child suggests the chromatography test that was used in Unit 15 in response to either question, show the class a four-ounce container that has a little water in it. Ask if anyone remembers how this was used with blotter strips before. If no child remembers, refresh their memories with the following demonstration.

With a pencil, draw a light line one-half inch from one end of a blotter strip. Using green coloring, make a dot on the blotter strip just above the pencil line. Place this dotted end into the small amount of water you have put into a four-ounce container.

Have the children observe and discuss what happens to the spot of color as the water rises in the blotter. When the water has risen about three-fourths of the way up the blotter (or about one inch from the top), remove the blotter and place it on newspaper to dry. The children will see that the green color separates into a column of blue-green with a yellow band near the top of the column.



Ask:

> HOW CAN WE USE THIS TEST TO HELP US DISTINGUISH OUR INK SPOTS FROM ONE ANOTHER? (Maybe the ink spots will separate into the colors that were used to make each particular ink. If different colors were used to make various inks, then perhaps their color separations may not be the same.)

Have each child come and get a piece of newspaper to protect his desk and a container with a little water in it. Ask each child to take the strip which he thinks has the Sheaffer ink on it and test it the way you just did the green spot. Go about the room checking to see that the children are not pushing the dots under the water, etc. Ask them to take the strips out of the water when the water has risen to within about one inch of the top of the blotter.

Results should vary, because not every child will have tested the correct dot. Have the children compare their color separations. Point out that all the separations are not alike. Suggest that maybe some children did not choose the Sheaffer dot. Ask:

> HOW CAN WE FIND OUT WHICH COLOR SEPARATION CORRESPONDS TO THE SHEAFFER INK? (Test the Sheaffer.)

As a demonstration prepare three blotter strips with Sheaffer ink dots. Emphasize the fact that you are using the same ink and are even taking it from the same cartridge. Mark each blotter with the name of the ink. Ask the children why you are using three dots instead of just one. (So that you can compare all three; if they all separate in the same way, you can deduce that this is the identifying pattern for Sheaffer's washable black ink.)

Place the three Sheaffer-dotted strips in a container with a little water. Space them around the container so that they are not touching or overlapping. Have the children observe what happens to the ink on each strip as the water rises in the blotter. Remove the strips when the water has risen about three-fourths of the way to the top. Place them on the table. Ask each child to bring the strip he thought was a Sheaffer ink dot (and which he has separated) and compare it with your three samples. If the child has the same separation as yours, he should mark his strip, "Sheaffer black ink."

Now discuss how the children might find out which kind of ink they tested, if it did not separate in the same way as your Sheaffer samples. (The children should suggest that you make some more samples. Perhaps then they can find out by comparing their separations with yours.)

Tell the children that you are going to do exactly that. Say that while they are doing the color separations on the three blotter strips they have not yet tested, you will be doing the following:

1. On three blotter strips, you will put dots of ink from Parker's permanent blue-black cartridge. Emphasize that you will take all three samples from the same cartridge and so should expect to get the same kind of color separation on each strip. Then you are going to place all three of these strips in the same container with a little water and get the separations.

2. You will use three more strips to test Parker's permanent black ink and place these in another container with a little water.

3. In a third container, you will test three other strips, each marked with a dot from the blue felt pen.

Before you and the children start making the separations, show them how they can place all three of their blotter strips in the same container to get the separations. Each blotter should be placed a little distance away from the others. Remind the children not to submerge the ink spots, but to let the water rise to the spots. Ask them to remove the blotter strips from the container when the water is within one inch of the top (or about three-quarters of the way up). If a child has submerged his dots, have him rinse out his container, make new dots and start over with four new blotter strips and all four inks.

When all the children have completed this experiment, have them discuss and compare their results. By comparing their results with the ones you have marked on the demonstration table, the children will discover that all the spots from a given ink will have separated into similar colors and patterns. They should now be able to identify each of the four inks they tested.

If the children haven't already done so, suggest that they bring in ball point pens and other kinds of pens with ink in them for testing in the next activity.

Activity B

This activity gives the children the opportunity to test several other inks and colored solutions (red felt pens and food colorings) and any others they may have brought from home or that are available in the classroom.

On a demonstration table, place the materials to be used -- the pens, food colorings, four-ounce containers with about one-eighth inch of water, blotter strips, and newspapers.

Give each child five or six blotter strips. Say that they can try any experiments with the colored liquids that they wish. Start them thinking about their experiments by asking these questions:

1. Will two different brands of ink or of food coloring that are the same color separate into the same colors and color patterns?
2. Will the red food coloring and the red felt pen ink separate in the same way?
3. Will any of the inks or colored solutions fail to separate? That is, will the ink spread but remain just one color?

4. Will any of the inks or other colored solutions remain in place when the water rises beyond them?
5. What will happen if a colored design is drawn on the blotter?
6. What would happen if two or more inks were put on the same spot?
7. What would happen if a very small dot of ink were used? A very large dot?

When the children have tested several colored solutions, discuss their results. The children should realize that chromatography (color separation) is a useful test for helping to identify colored solutions. In a similar way, the properties of hardness and density were useful in helping to identify minerals, metals and other materials.

If blotting strips are left in the water long enough, all of the colors will eventually rise to the top of the blotter. This spoils the separation pattern, but you might like to have the children try it.

You might also like the children to discuss their thoughts about why some inks from ball point pens separated little, if any, and also why the black pencil line did not separate. Accept any reasonable answers as suitable at this level.

SECTION 6

PROPERTY OF SHAPE

SECTION 6 THE PROPERTY OF SHAPE

PURPOSE

- To have the children learn that the property of shape helps to identify some materials.
- To have them discover that some minerals have identifiable geometric shapes.
- To have the children investigate some of these shapes carefully by building models, counting the number of sides and measuring the face angles.

COMMENTARY

In Lesson 12 the children examine eight different white substances with magnifiers and discover that the particles of which some substances are made are so fine that they can discern no particular shape. The children also look at metal and mineral samples for the property of shape. The particles (crystals) of which metals are made cannot be seen with hand magnifiers, but the children are able to see the shapes of larger crystals in quartz and corundum samples.

A story, "Super-Sleuth and Studious Jones," provides motivation for the work with crystal shapes that the children do in Lessons 13, 14 and 15. The work consists of examining the shapes of quartz, corundum and calcite and of model building as well as angle measurement. The children use transparent protractors from the special printed MINNEMAST materials to measure angles.

In Lesson 16 the children see how cleavage affects the property of shape. After working with the real mineral, they build a model of calcite, and use their protractors to discover some interesting facts about the angles of this particular shape. By the end of this lesson the children will understand how the property of shape can provide one more clue to the identification of a material.

Teaching time for this section should be about five class periods.

Lesson 12: IS THE PROPERTY OF SHAPE USEFUL?

The purposes of this lesson are (1) to have the children learn that the property of shape characterizes some materials, and (2) to have them discover that this property may be used, together with other properties, in identifying certain materials.

The children attempt to identify several materials by the property of shape. In Activity A they compare what they see through their magnifiers with magnified photographs of the same white substances. Some of the white substances have small components or "grains" with a characteristic shape that suggests they might be identified by this property. Other white substances that the children examine do not have small component particles of any specific shape.

In Activity B the children observe the metal and mineral samples used in previous lessons in an attempt to identify these by the property of shape. Many of the materials do not have a characteristic shape, but a few of the mineral samples seem to. The children are then challenged to figure out in what way the shape of quartz and corundum crystals are alike. This leads to further studies of crystal shapes in the next lesson.

MATERIALS

-- for the class --

- in 4-ounce plastic containers, samples of each of the following:
- A, Epsom salt
- B, starch
- C, powdered chalk
- D, plaster
- E, baking soda
- F, detergent

(all of the above are in the OMSI kit)

- G, sugar

- H, salt
- 8 plastic spoons (in kit)
- 30 magnifiers
- metal samples from kit
- mineral samples from kit

-- for each child --

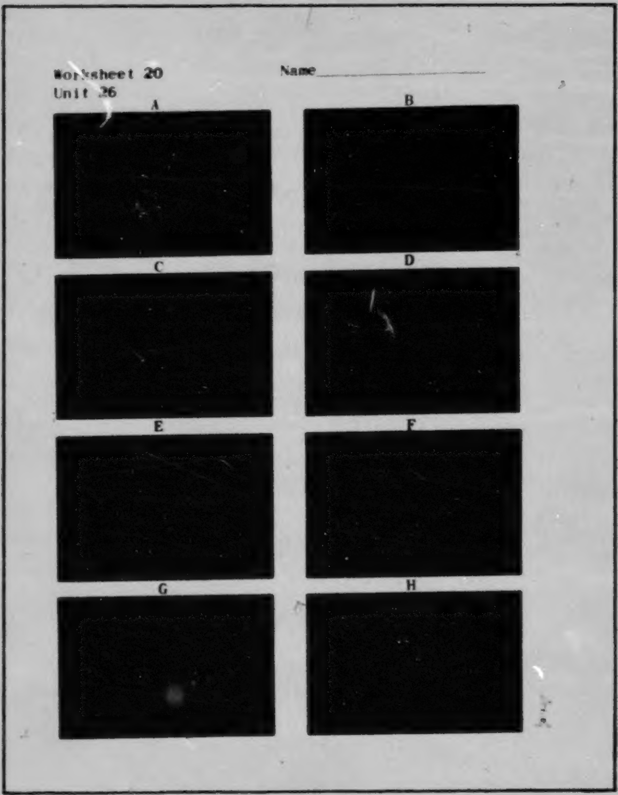
- Worksheets 20, 21 and 22

PREPARATION

Before class starts, place on a large cafeteria tray the eight white substances in their containers. Label each container with a letter as indicated in the Materials List. Put a plastic spoon in each container.

PROCEDURE

Activity A



Worksheet 20
Unit 26

Name ______________________

Ask the children to remove Worksheet 20 from their Student Manuals. Tell them you have eight white substances that you would like them to try to identify. List the names of the white substances on the chalkboard, but not in order and not lettered. For example, you might want to list them in this way:

salt
plaster
starch
sugar
Epsom salt
chalk
detergent
soda

Tell the children that each of them will get a sample of each substance. A small sprinkling of substance A will be placed on region A of the worksheet, etc. When each child has a sample of each substance, you will want the children to try to tell you -- by observation -- which is plaster, which is starch, and so on.

Select eight children to distribute the white substances. Assign one child to distribute each substance. The child with container A, for example, should use the spoon to sprinkle a small sample over region A of every child's Worksheet 20.

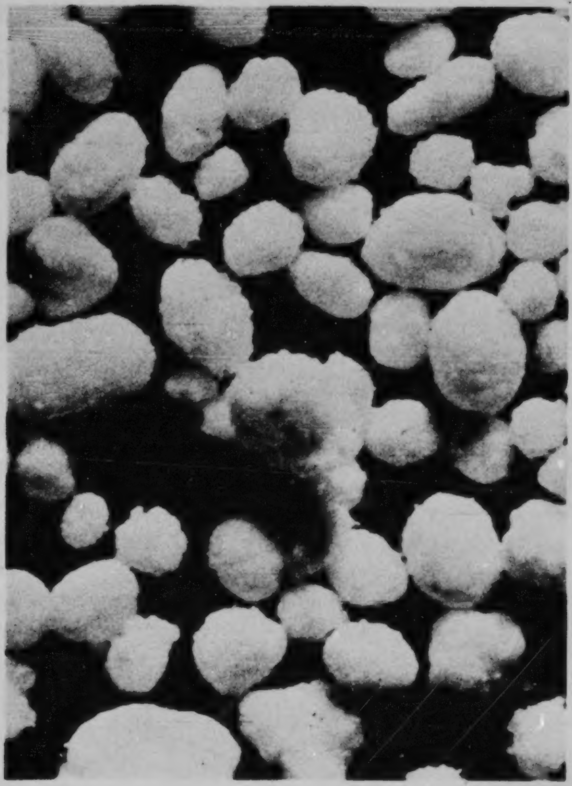
When all the children have samples of the eight substances, ask them which is sugar, which is salt, which plaster, etc. The children should realize quickly that it is quite difficult to identify these white substances. Ask them to describe the properties of the substances. Be sure these descriptions include such properties as color, shape and texture. List the children's suggestions on the chalkboard. The list might look something like this:

white
lumpy
grainy
powdery
tube-shaped
glassy

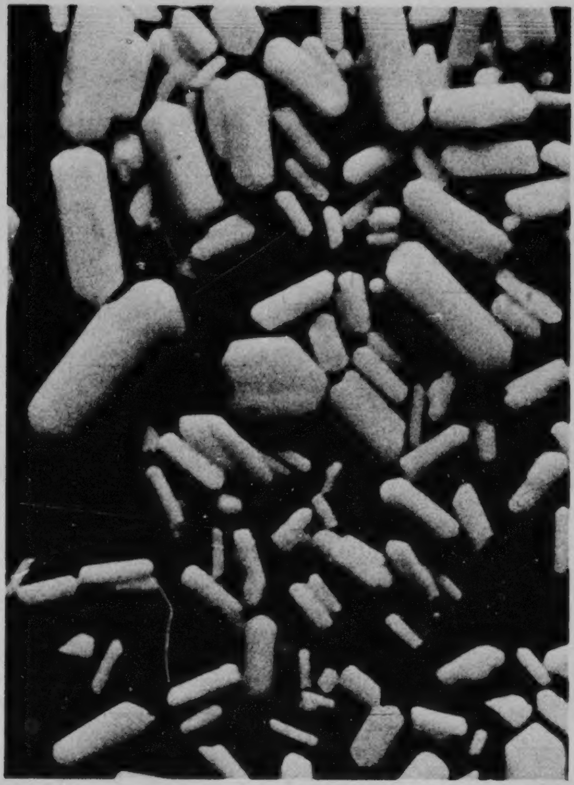
Now ask which properties of the substances seem to be the same and which seem to be different. The children should agree that all the substances are white, but that their textures or shapes appear to be different. Elicit from the children the idea that maybe the property of shape could be used to help identify their white substances.

Have the children remove Worksheets 21 and 22 from their Student Manuals.

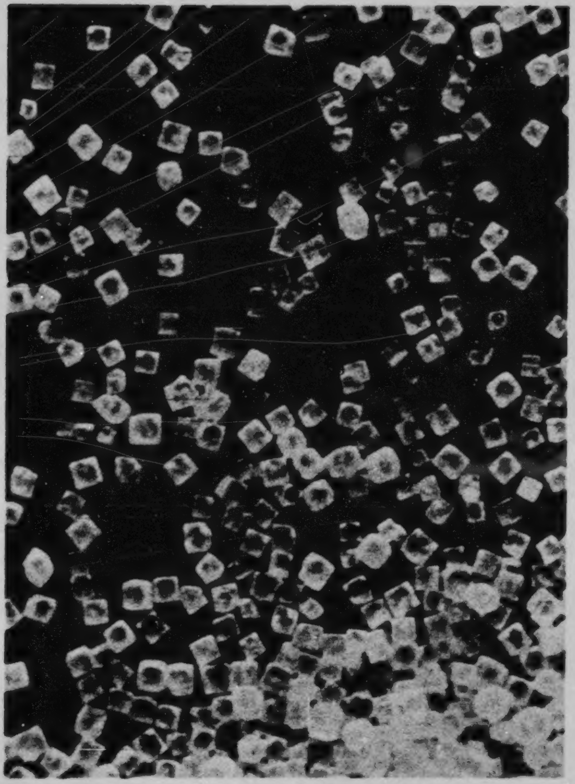
Worksheet 21 Unit 26



Detergent



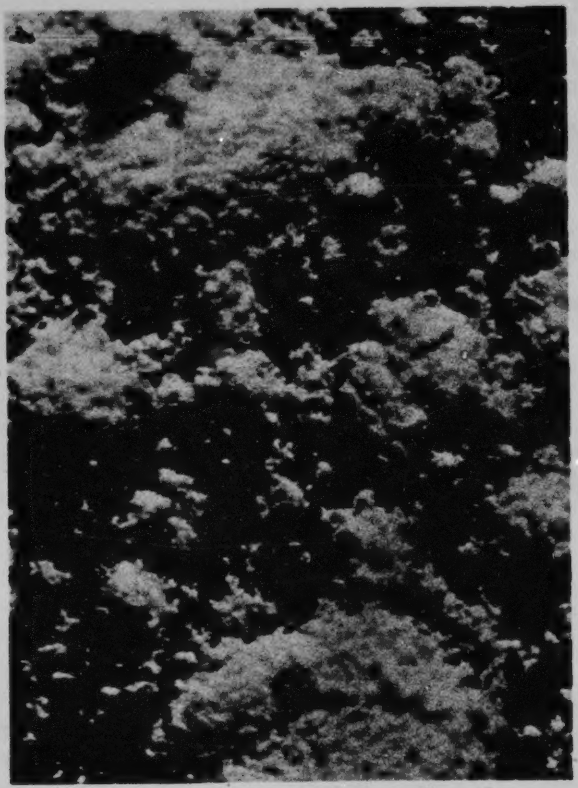
Epsom Salt



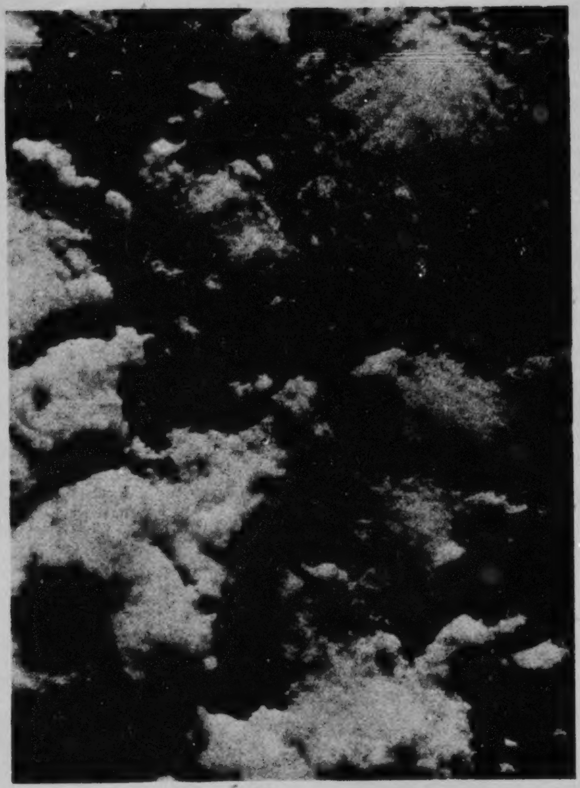
Salt

Sugar

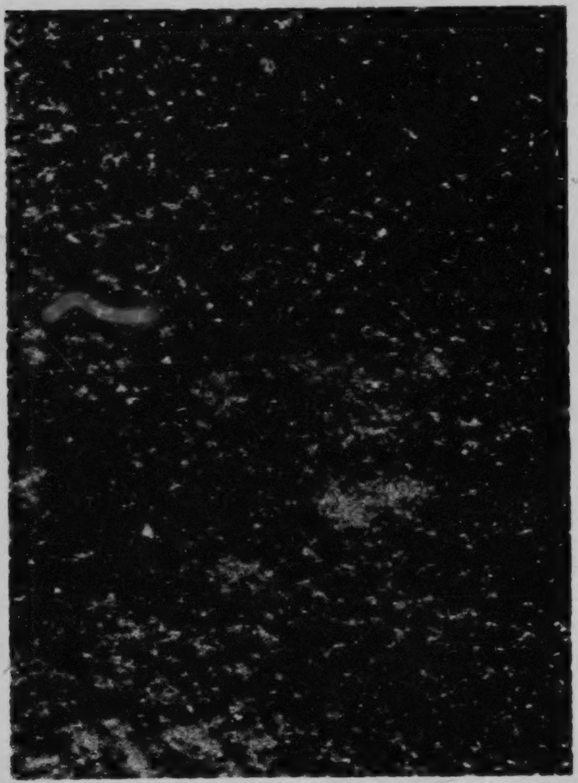
Worksheet 22 Unit 26



Plaster



Starch



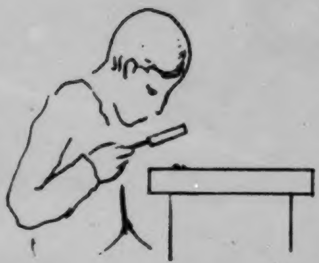
Soda

Chalk

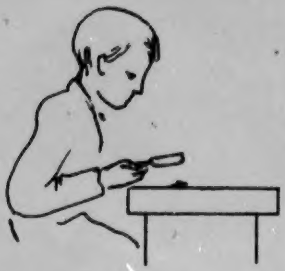
Discuss the eight photographs on these worksheets with the children. Ask how the photographs are different from what the children see when they look at their samples. Tell the class that the photographs were taken by a camera that enlarges (scales up) things by a factor of ten. This means that each photograph shows sugar, salt, etc., ten times larger than it really is. Ask what the children could do to see the substances better and so observe the shapes of the particles better. (They should suggest using magnifiers or microscopes.)

Give each child a magnifying glass. Ask them to use the smallest of the three lenses. This lens magnifies the particles by a factor of five. Show the children how to use the hand lens correctly. The lens should be close to the eye and to the object being studied -- not more than three to four inches from either.

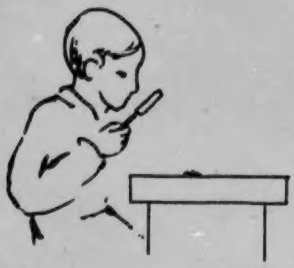
Correct



Wrong



Wrong



The children should try to identify their white substances by comparing what they see through their magnifying glasses with the photographs on the worksheets. They probably will be able to identify the Epsom salt, detergent, salt and sugar. (The salt and sugar are both cubic in shape, but the salt is much more uniform and less broken.) The plaster, chalk, starch and soda are quite similar in appearance and it is hard to distinguish one from another. Emphasize the idea that sometimes the property of shape is helpful in identifying a material, and sometimes it is not.

Activity B

Have a few metal objects on hand. Then ask the children:

> IS THE PROPERTY OF SHAPE USEFUL IN IDENTIFYING THE METAL SAMPLES?

Let the children quickly examine some of the metal pieces. Obviously, shape is not useful in this case. Discuss other materials where shape does not help in identification. For example, wood may be in the shape of a chair or a pencil, plastic may be almost any shape, and so may glass.

Bring out the mineral samples that the children used in the hardness tests. Ask:

> WOULD THE PROPERTY OF SHAPE BE USEFUL TO US IN IDENTIFYING THE MINERAL SAMPLES?

Sort into piles all the samples of fluorite, calcite, apatite, quartz and corundum. Divide the class into five groups and give each group all the samples of a particular mineral.

Ask each group to examine its set of a particular kind of mineral. Ask the children to try to determine whether or not the property of shape would help them identify their mineral. See if they can find a characteristic shape for the mineral.

Tell the children that some of the minerals in the sample set are not being used in this activity because they had been cut or sawed off and therefore have an arbitrary shape. If they found a natural sample of one of these minerals it wouldn't have the same shape and they wouldn't be able to identify it.

Have each group choose a spokesman to report to the entire class on their observations. Use the following information as your guide to the discussion.

1. Flourite (#4) appears to have an irregular shape. It was probably broken off from a larger piece.

2. Calcite (#3) appears to have a definite shape. Its faces are parallelograms.

3. Apatite (#5) seems to have definite faces, although the pieces are rather difficult to examine.

4. Quartz (#7) samples all appear to have a similar shape.

5. Corundum (#9) samples all seem to have a similar shape.

Tell the children that the quartz and the corundum have shapes that are considered to be alike in some way. Leave the specimens of these two minerals out on the demonstration table for the next lesson.

Lesson 13: EXAMINING THE SHAPE OF QUARTZ CRYSTALS

In the last lesson the children observed a number of materials and discovered that the property of shape is useful in identifying some of them. In this lesson they will concentrate on crystal shapes. They will look at quartz crystals and try to describe the shape. Then they will make a model of an idealized quartz crystal (with both ends sawed off) for study in the next lesson. A story gives some elementary information about crystals and provides motivation for the children's observations, discussions and model building.

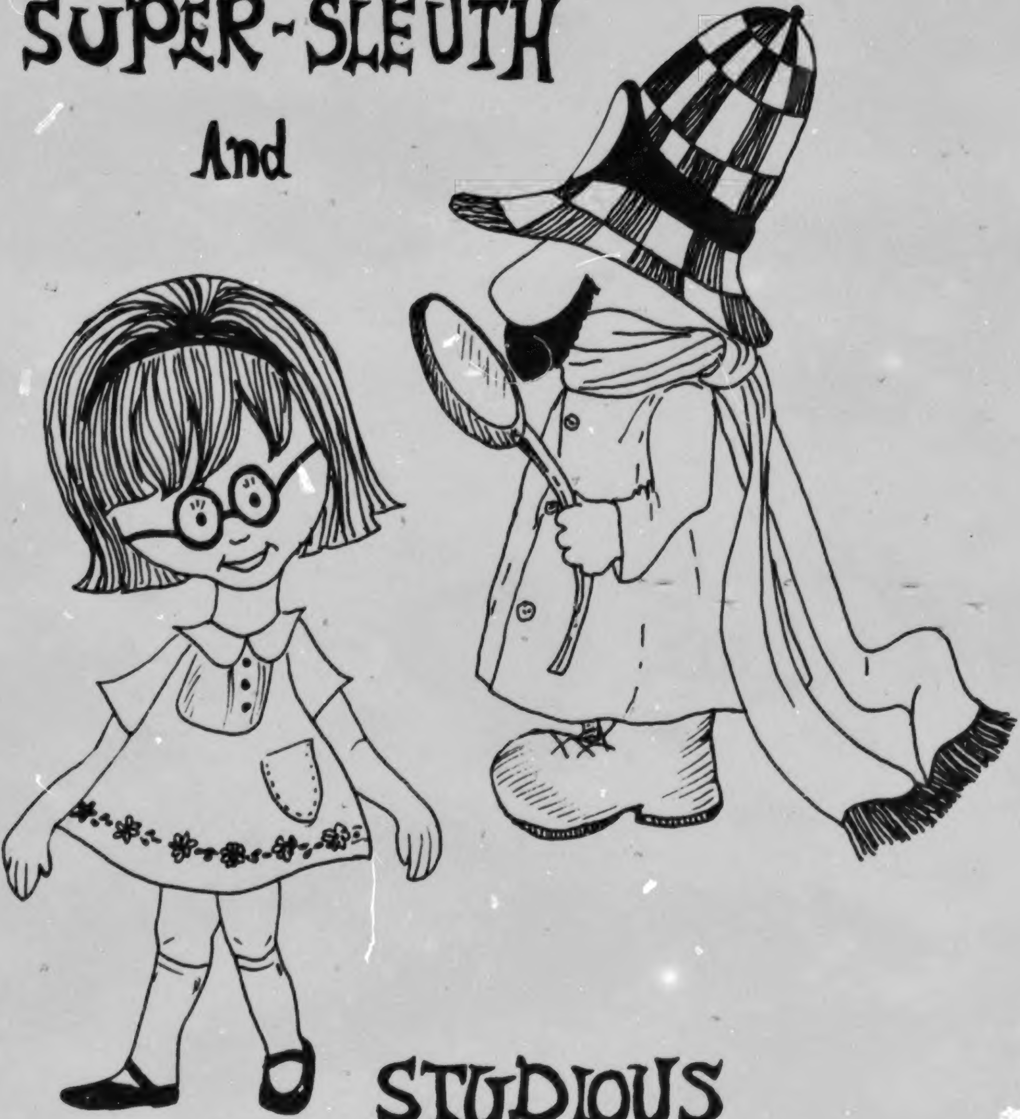
MATERIALS

- 8 quartz crystals
- story, "Super-Sleuth and Studious Jones" (provided in this lesson and also in the Student Manuals)
- Worksheet 23 (quartz crystal model printed on heavy paper)
- scissors
- cellophane tape

PROCEDURE

Have the eight quartz samples handy on a demonstration table in a clear area of the room. Ask the children to bring their Student Manuals and come to this area. Have them sit down and open their manuals to the story, "Super-Sleuth and Studious Jones." Begin reading the story to the children and ask them to follow along in their own books as you read. Stop at each place in the story where Super-Sleuth is asked to make a discovery, and have the children make their own discoveries first. Then pick up the story. Conclude the lesson with the making of the quartz crystal models for use in the next lesson.

SUPER-SLEUTH
And
STUDIOUS JONES



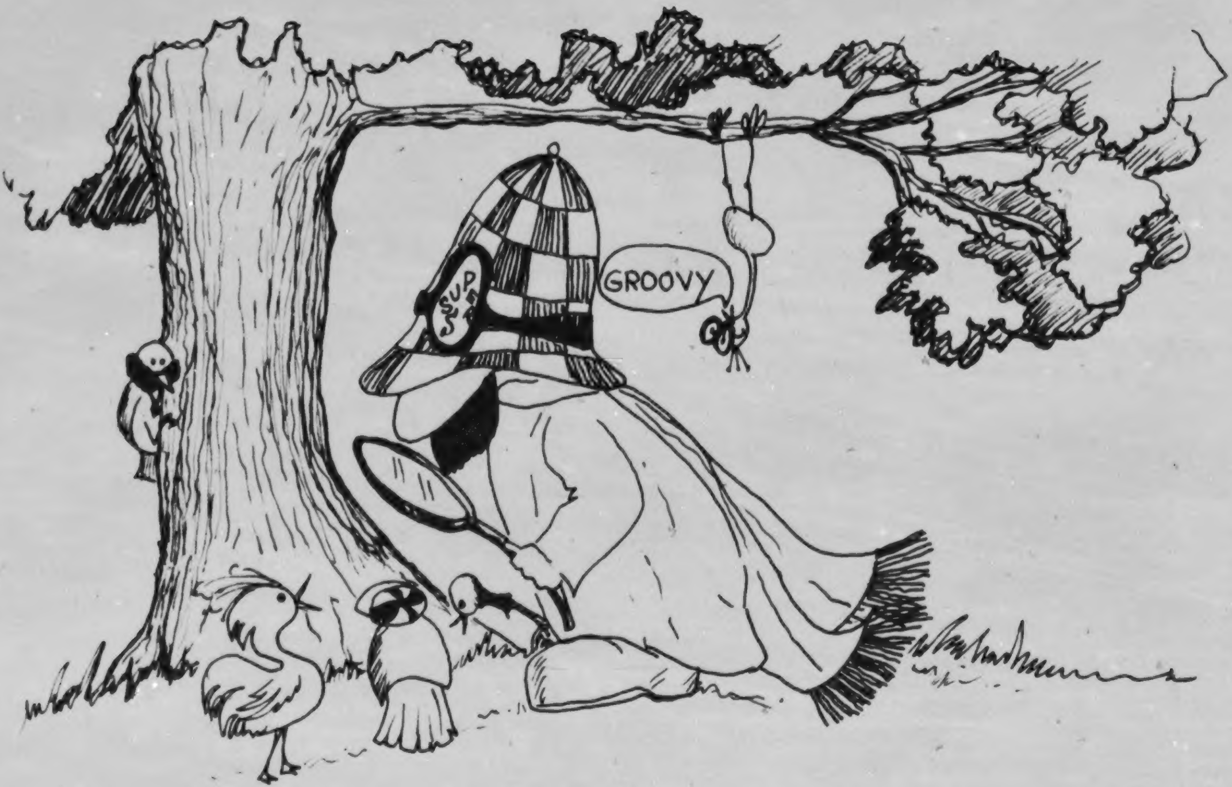
Story by Elaine Vogt

Illustrations by Sonia Forseth

WILL SUPER-SLEUTH EVER LEARN ABOUT CRYSTAL SHAPES?
WILL STUDIOUS JONES KNOW HOW TO TEACH HIM?
WILL HE BELIEVE WHAT SHE TELLS HIM?
WOULD YOU LIKE TO FIND OUT ABOUT CRYSTAL SHAPES, TOO?

FOR FUN AND AMAZEMENT, AND EVEN SOME FACTS,

READ AHEAD →



SUPER-SLEUTH AND STUDIOUS JONES

Super-Sleuth thought he was a great detective. He went around wearing a very strange hat and looking at things through a magnifying glass. The children in his neighborhood knew that Super-Sleuth was not very bright, but they all liked him because he was interested in so many things. They also liked the talking birds that followed him everywhere, and were so saucy and cheerful.

On this particular day Super-Sleuth and his birds were inspecting a tree. He was saying to them, "My, my, my, it is certainly hard to tell what material this tree is made of by looking at it. Even my magnifying glass doesn't seem to help."

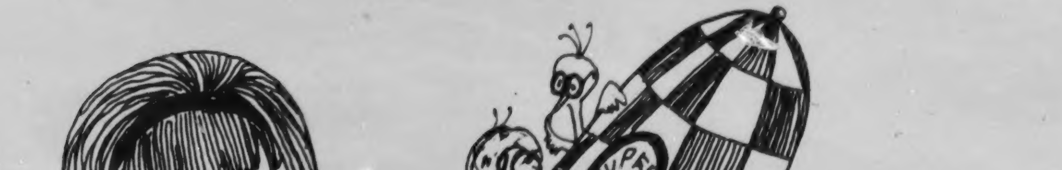
Super-Sleuth thought he might have better luck if he looked at some other kinds of materials. He got down on his knees and looked at some sand. "My goodness," he exclaimed, "this sand is made up of little things that are very hard to see!"

Just then a girl who was in the sixth grade came along. Her name was Studious Jones and she was on her way home from school. "Those little things you are looking at, Super-Sleuth, seem to be sand in crystal form. Quartz is often found in crystal form, too."

"H'mm, where else do we find crystals?" Super-Sleuth asked.

"You can find them in a penny," Studious replied.

"A penny! Why, you must be fooling," Super-Sleuth said. Then he took a penny from his pocket and looked at it through his magnifying glass. His birds flew up and perched on his hat and shoulders so that they could look, too. "I can't see any crystals in this penny," Super-Sleuth said. "Here, Studious, take a look."


WOW!
SUPER
S
LET ME SEE IT TOO.

"I don't have to look," Studious Jones replied. "I already know that copper crystals are too small to be seen through a magnifier."

"How do you know that copper material is made up of crystals at all, Studious?" Super-Sleuth asked.

"Well, its a pretty well-known fact that some fluids take a definite shape or pattern when they become solid. These kinds of materials are called crystals. When melted copper fluid cools off, it forms absolutely beautiful crystals! But you need a powerful microscope to see them."

Super-Sleuth continued to look at the penny. He found it very hard to believe that Studious Jones was telling him the truth.

Studious decided that Super-Sleuth needed a simpler example. She said, "Do you think snowflakes are crystals, Super-Sleuth?"

"Um, yes . . . yes, indeed."

"Well then, what happens that makes snowflakes?"

"How should I know?" Super-Sleuth asked.

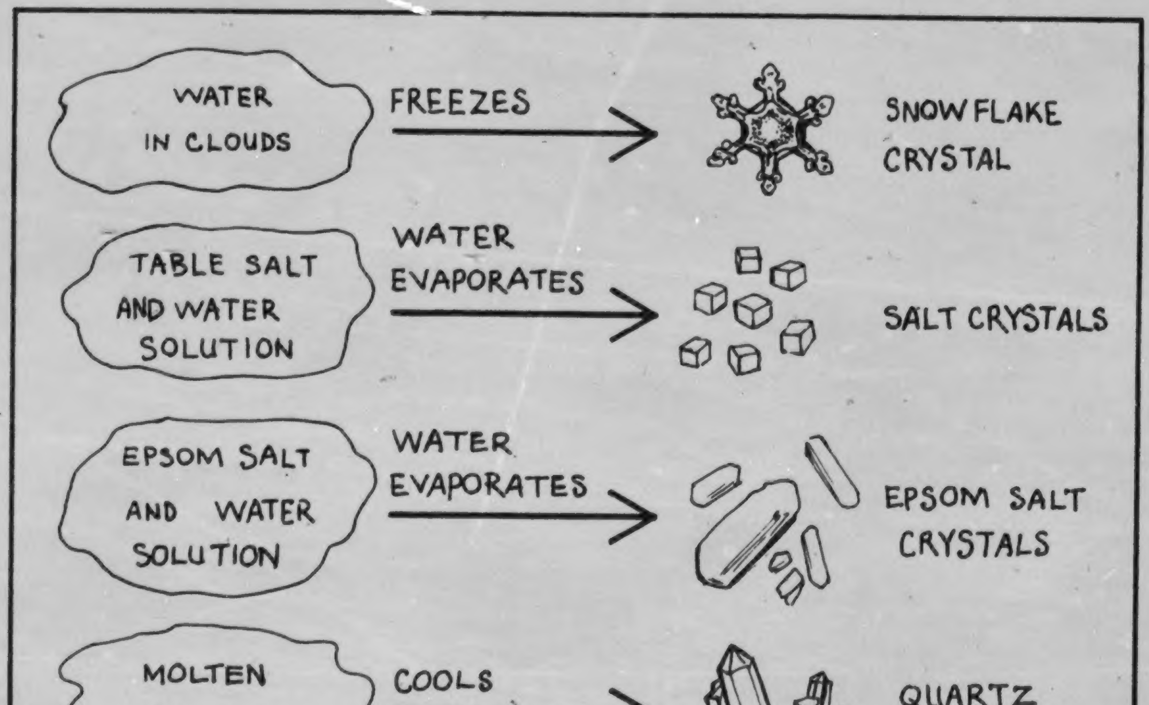
Studious thought a grown man ought to know what made snowflakes, but she decided to be patient. "When it's cold, Super-Sleuth, the tiny drops of water in the clouds freeze. The water changes from a liquid to a solid -- and, presto, you have snowflakes!"

"Well, all right, I believe you about the snowflakes," Super-Sleuth said, "but you ought to tell me more about how fluids turn into crystals."

Studious puckered up her face. She was thinking. Then she took some paper and a pencil from her book bag and started drawing. "The best way to teach you about crystals is to show you some of the different shapes they take." This is what Studious drew for Super-Sleuth.

THESE ARE THE LIQUIDS.

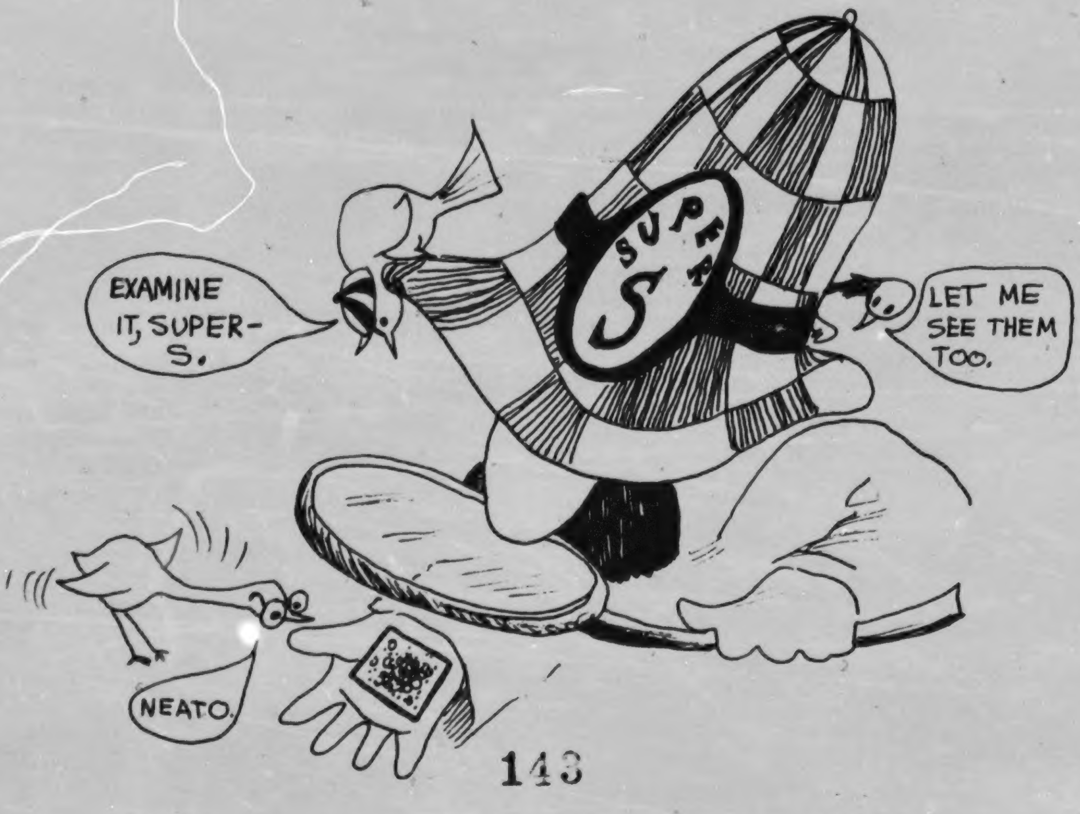
THESE ARE THE CRYSTALS


WATER IN CLOUDS
FREEZES
SNOW FLAKE CRYSTAL
TABLE SALT AND WATER SOLUTION
WATER EVAPORATES
SALT CRYSTALS
EPSOM SALT AND WATER SOLUTION
WATER EVAPORATES
EPSOM SALT CRYSTALS
MOLTEN ROCK
COOLS
QUARTZ CRYSTALS
MOLTEN ROCK
COOLS
CORUNDUM CRYSTALS

Super-Sleuth looked puzzled. Studious said, "Look at the crystal shapes. Look at the table salt, the Epsom salt, the quartz and the corundum. What do you notice about the different kinds of crystals, Super-Sleuth?"

"Um . . . um . . . I don't know," Super-Sleuth mumbled. Then he pointed to the table salt and Epsom salt crystals. "I can tell you one thing, though -- I bet these two both taste salty." Super-Sleuth puffed up his chest. He thought he had made a wonderful discovery.

But Studious Jones was annoyed. "Scientists do not go around tasting things," she said. "You could get sick by doing that. Besides we are talking about the shapes of the crystals, not anything else. Now, what do you notice about the shape of the salt crystals?"

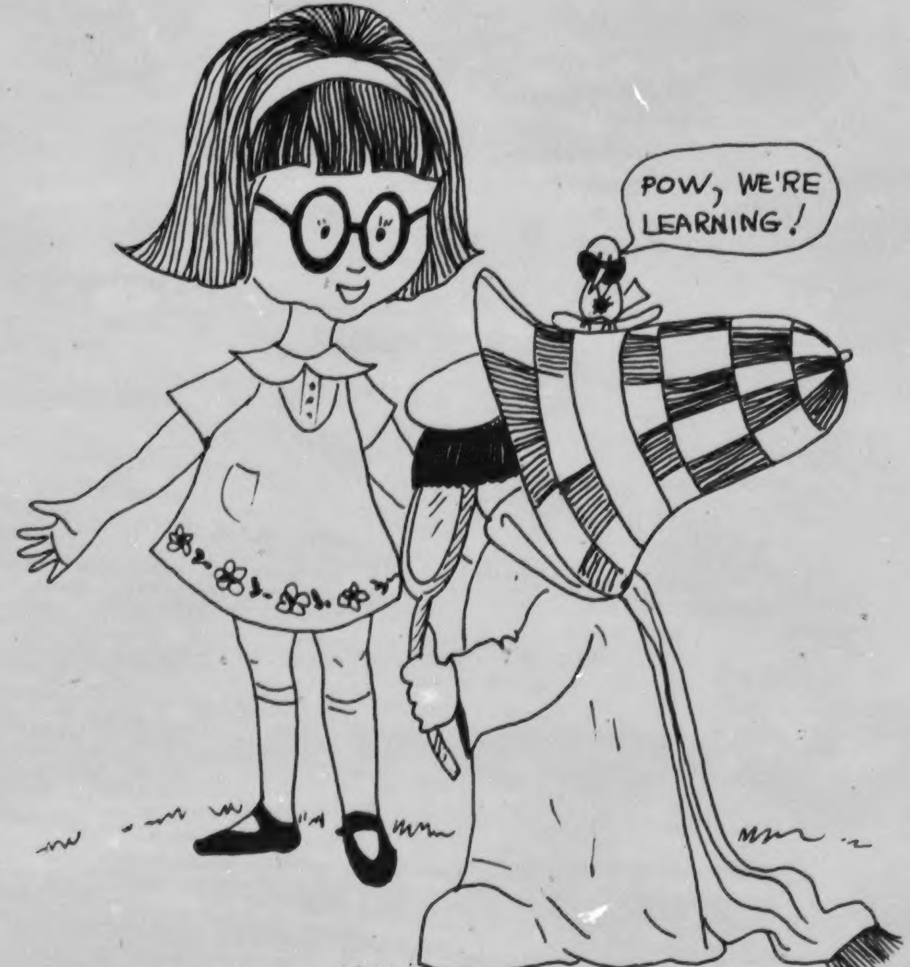

EXAMINE IT, SUPER-S.
SUPER S
LET ME SEE THEM TOO.
NEATO.

Super-Sleuth looked at the pictures again. After hemming and hawing, Super-Sleuth finally said, "Well the salt crystals seem to be shaped like little boxes."

"They are cubes . . . they have a cubic shape," Studious said.

"Well, that's what I meant," Super-Sleuth said.

"Great," Studious said. She felt better now about Super-Sleuth. Maybe she could teach him something about crystal shapes, after all. She decided to keep trying.


POW, WE'RE LEARNING!

YIKES! QUARTZ.
LET ME SEE IT TOO.
SUPER S
WHAT A GREAT ROCK PILE.

She reached into her book bag and brought out some small objects. "A while ago I talked about quartz crystals to you, Super-Sleuth. Maybe it would help you to learn about crystals if you looked at some real ones. I borrowed these quartz crystals from the third grade teacher to help with my study of crystal shapes," she explained.

"The third grade!" Super-Sleuth exclaimed. "Do you mean to tell me the children in the third grade are studying crystals?"

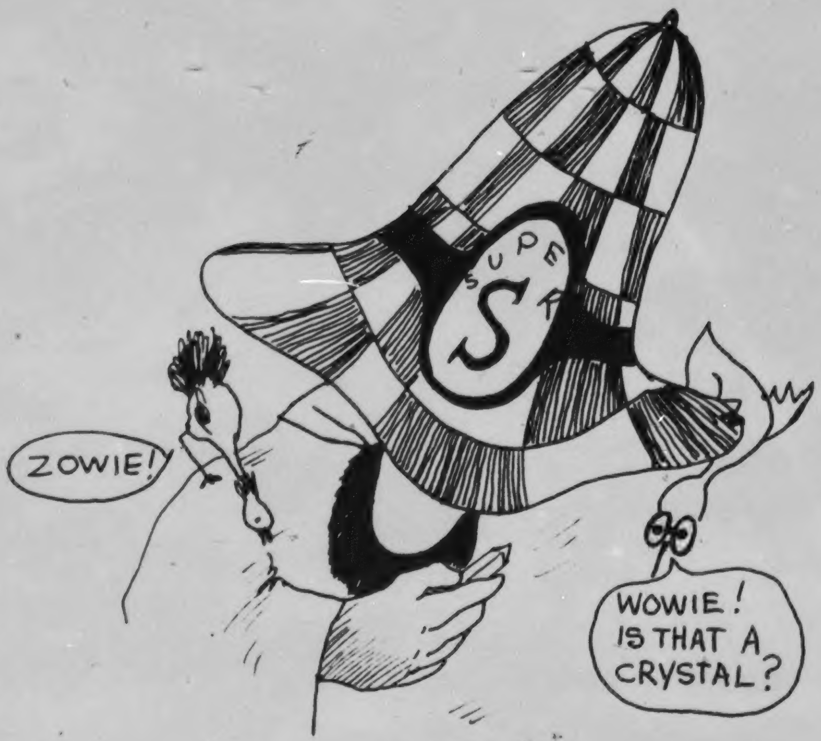
"They are now," Studious Jones replied. "But they weren't when I was in that grade."

"Oh, these modern times!" was all Super-Sleuth could manage to say. His eyes got a faraway look as he thought how marvelous it was that children in the third grade were studying crystal shapes.

Studious Jones had to cough to get his attention back to the quartz crystals. "Please, Super-Sleuth," she said, "look at these quartz crystals and tell me what is alike about all of them."

Poor Super-Sleuth. He looked at each crystal -- both with and without his magnifying glass. He turned and turned each piece. Then he tried comparing two pieces at a time. After all this, he said, "The quartz crystals sort of look and feel like clear glass."

"Those observations are all right for a beginning, Super-Sleuth, but I think you should be able to discover something interesting about the shape of the quartz crystals. Why don't you touch them again, and turn them, and try to find out if the surfaces are rounded or flat, or jagged and pointed?"


SUPER S
ZOWIE!
WOWIE! IS THAT A CRYSTAL?

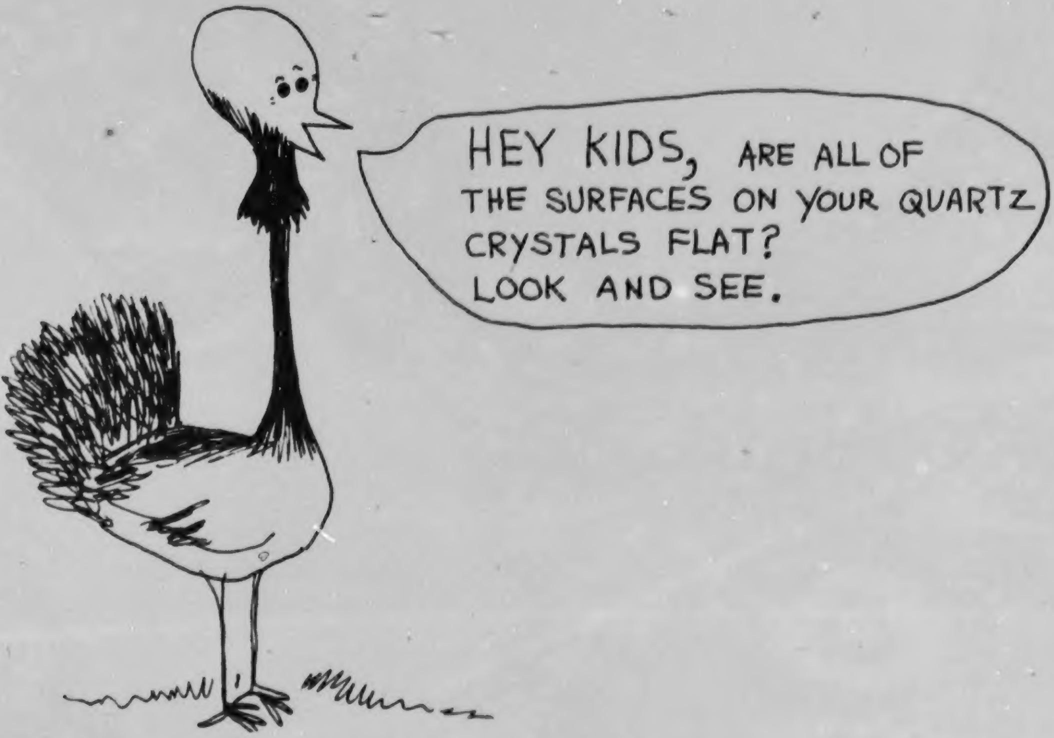
"All right, all right," Super-Sleuth said, and he began examining the crystals more carefully. He was anxious to discover whatever secret it was that Studious Jones knew about these crystals that he didn't know.

"Yippee!" Super-Sleuth shouted in joy. "Studious, what do you think I have discovered?"

"I don't know. What?"

"Why, there are some flat surfaces on every one of these quartz crystals. Isn't that fantastic?" All the birds fluttered about, repeating, "Fantastic! Fantastic! Fantastic!"

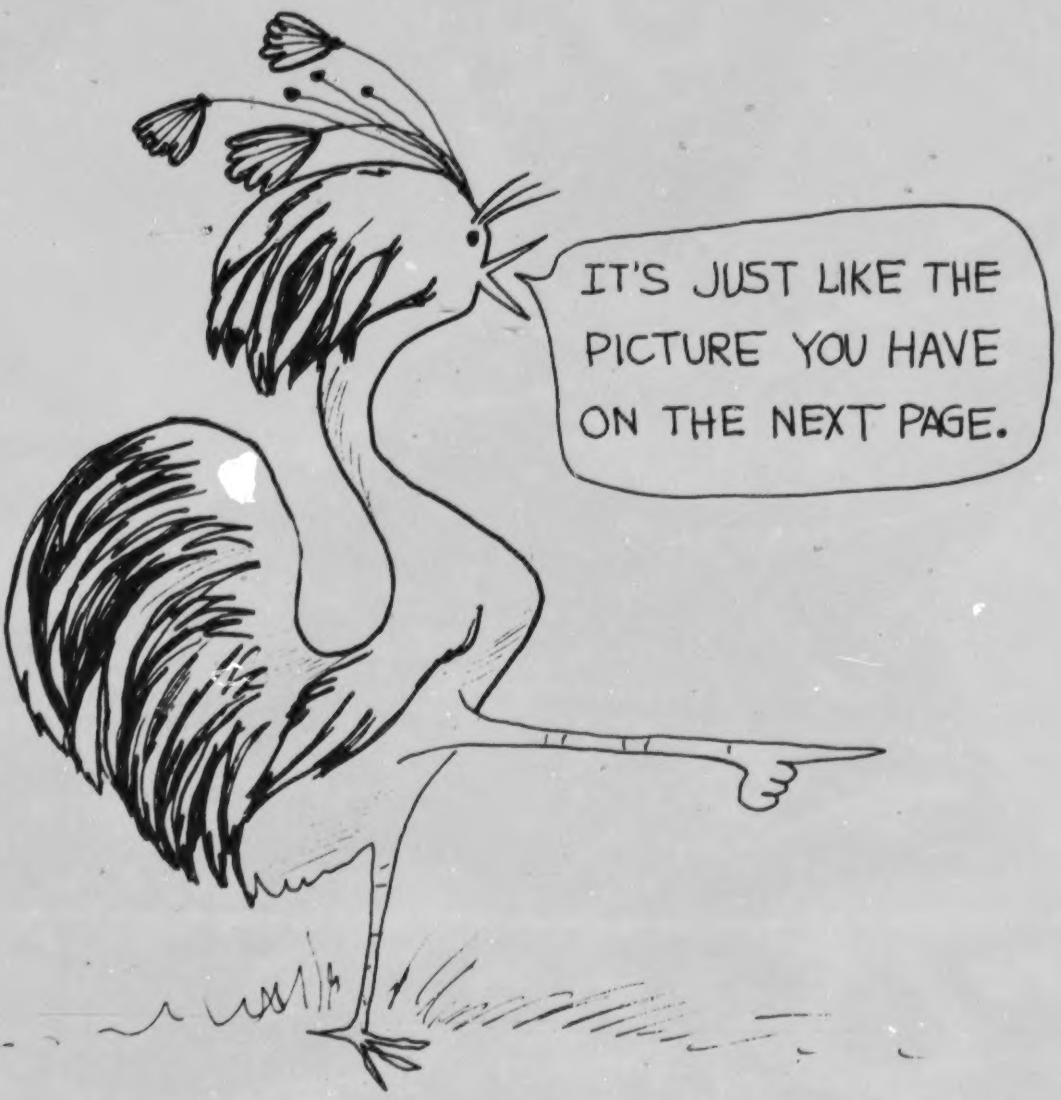
Studious smiled. Then she asked, "Are all of the surfaces flat, Super-Sleuth?"

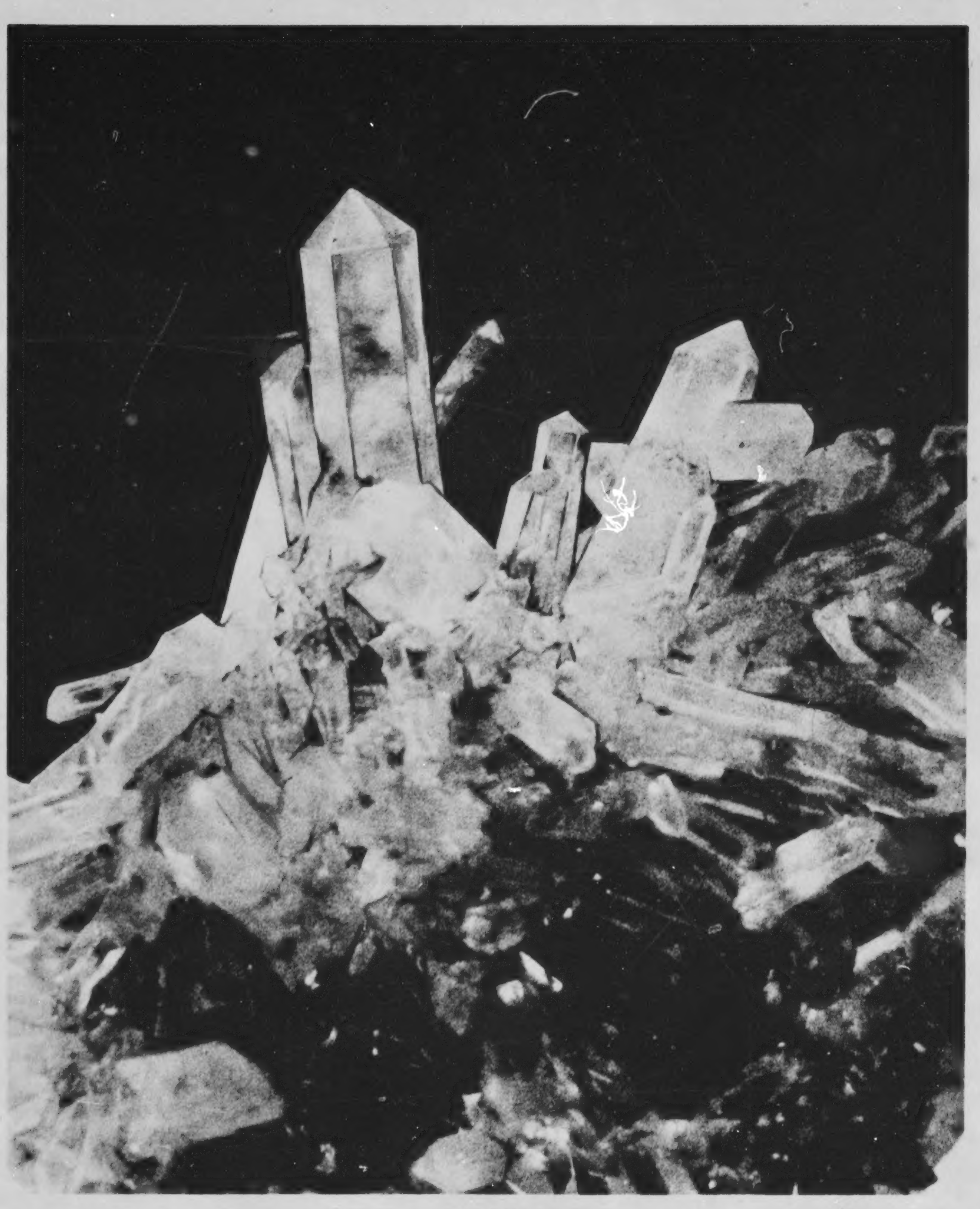

HEY KIDS, ARE ALL OF THE SURFACES ON YOUR QUARTZ CRYSTALS FLAT? LOOK AND SEE.

"Well, no, Studious. This crystal right here, for example, is jagged and rough on one end. But the other end has some flat surfaces that seem to come to a point. Why is one end rough and the other end pointed?"

"Yes, why? Why? Why?" the birds all asked, too.

Studious took a book from her bag and found a picture of a cluster of quartz crystals. She showed it to Super-Sleuth.


IT'S JUST LIKE THE PICTURE YOU HAVE ON THE NEXT PAGE.

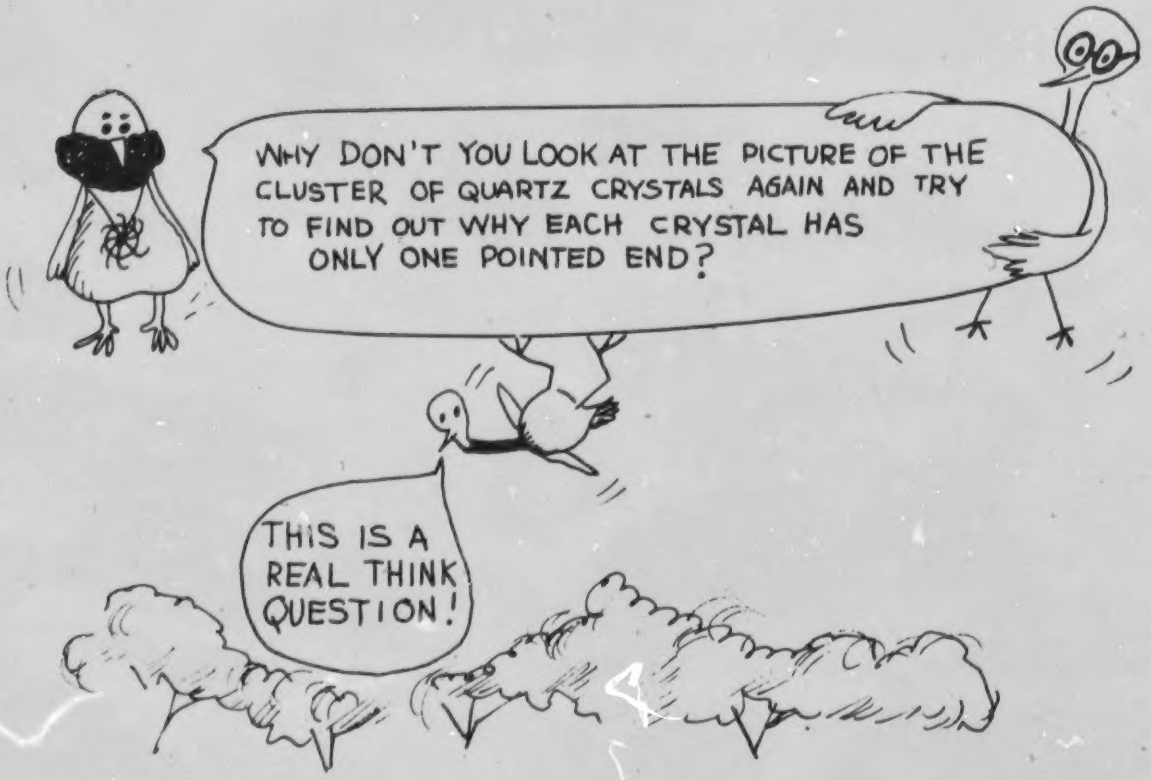


Super-Sleuth looked at the picture. "Oh, my goodness, Studious! What a jumble! Are these all quartz crystals? What in the world is wrong with them?"

"Yes, what's wrong with them? What's wrong with them?" The parrot tipped his head saucily and looked straight at Studious.

Studious laughed. "There's nothing wrong with them. That's just the way quartz crystals are formed -- in clusters. Some people say that's the way they 'grow,' but they don't mean exactly the same kind of growing that plants do. Now, Super-Sleuth, when you look at this cluster of quartz crystals, does it tell you why each crystal has only one pointed end?"

"Let me guess! Let me guess!" Super-Sleuth pleaded.


WHY DON'T YOU LOOK AT THE PICTURE OF THE CLUSTER OF QUARTZ CRYSTALS AGAIN AND TRY TO FIND OUT WHY EACH CRYSTAL HAS ONLY ONE POINTED END?
THIS IS A REAL THINK QUESTION!

HIP, HIP!
HE'S GOT IT!
HOORAY!

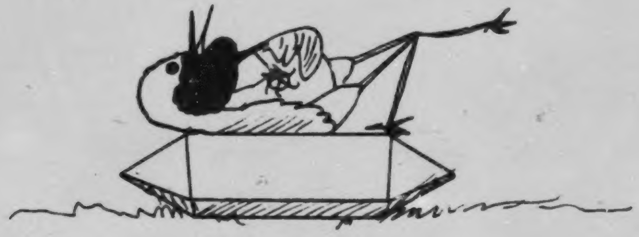
"I've got it! I've got it!" Super-Sleuth shouted suddenly. And all the birds joined in the chorus.

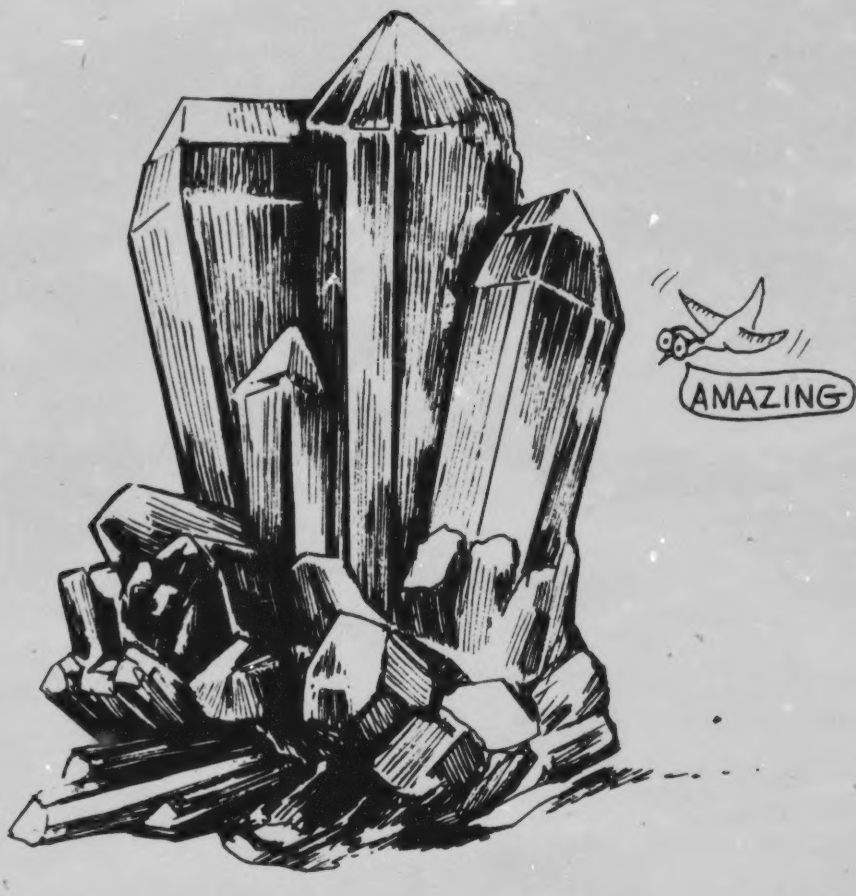
"What?" Studious asked.

"Why, these quartz crystals we have been looking at -- the real ones -- are just part of a bunch like those in the picture. Somebody must have broken each one from the bunch, and that is why each crystal has only one pointed end."

"You're practically a genius, Super-Sleuth," Studious said, and the birds all repeated happily, "A genius! A genius!"

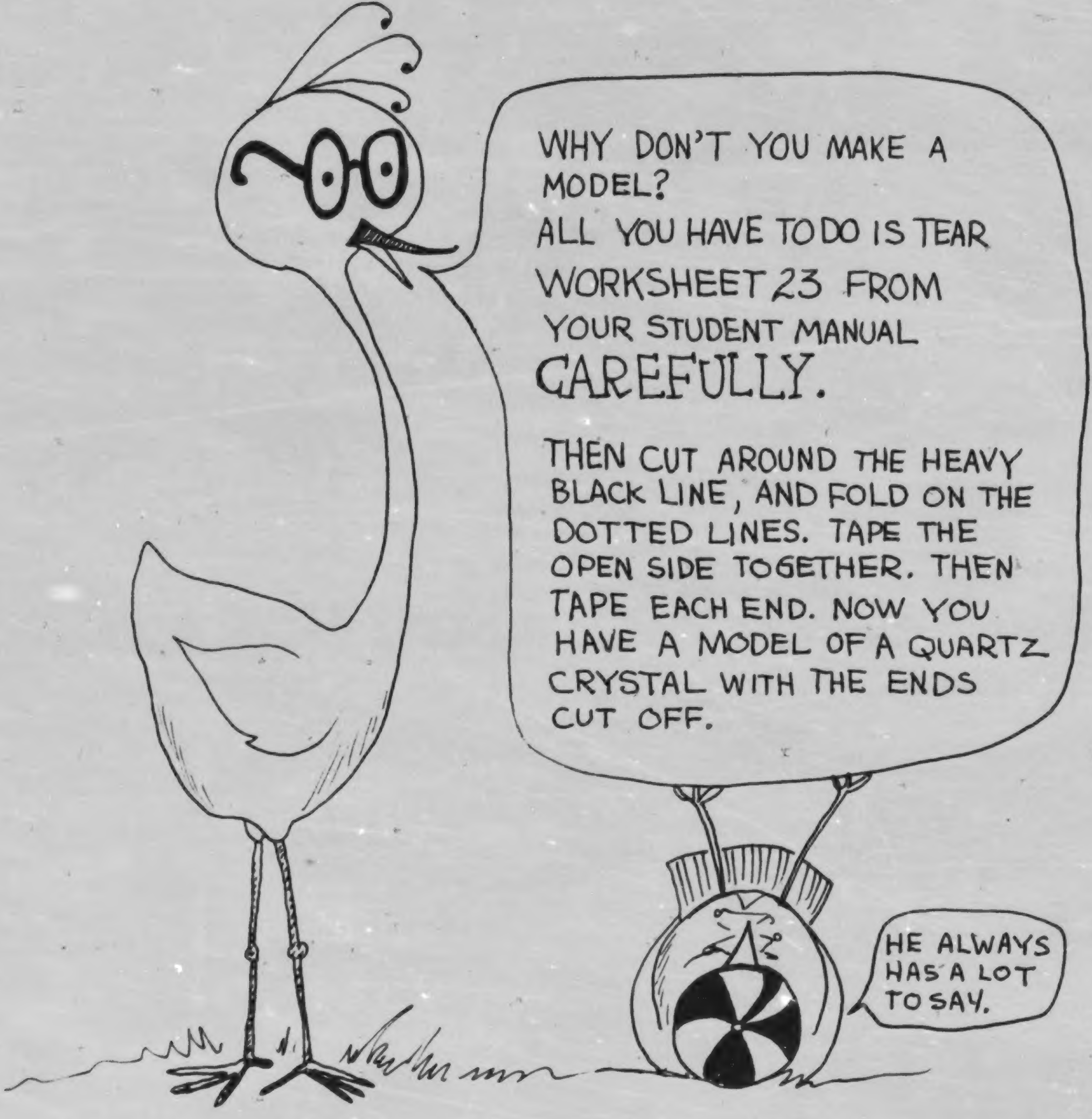
Super-Sleuth blushed. "Oh, I wouldn't go so far as to say that yet," he said, "because I think there is more that I should find out about this crystal business."





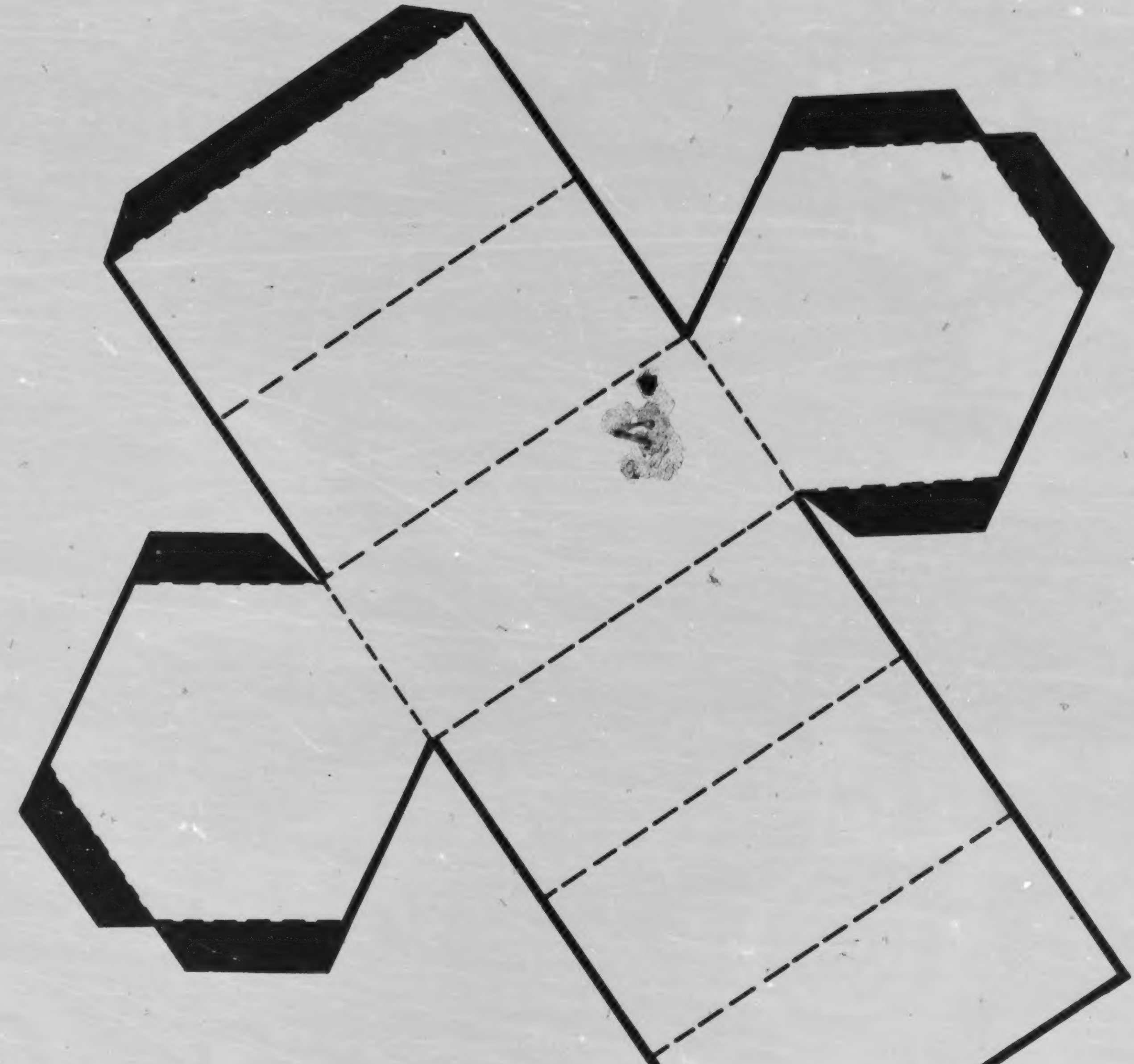
"Because they have broken ends, and because some don't even have a point, these quartz samples are not very easy to observe. It's very hard to tell just what shape they are." Super-Sleuth picked up a quartz crystal and stared at one end of it. Then he stared at the other end of it. Then he heaved a big sigh. The birds all sighed, too, and looked toward Studious, as though expecting help.

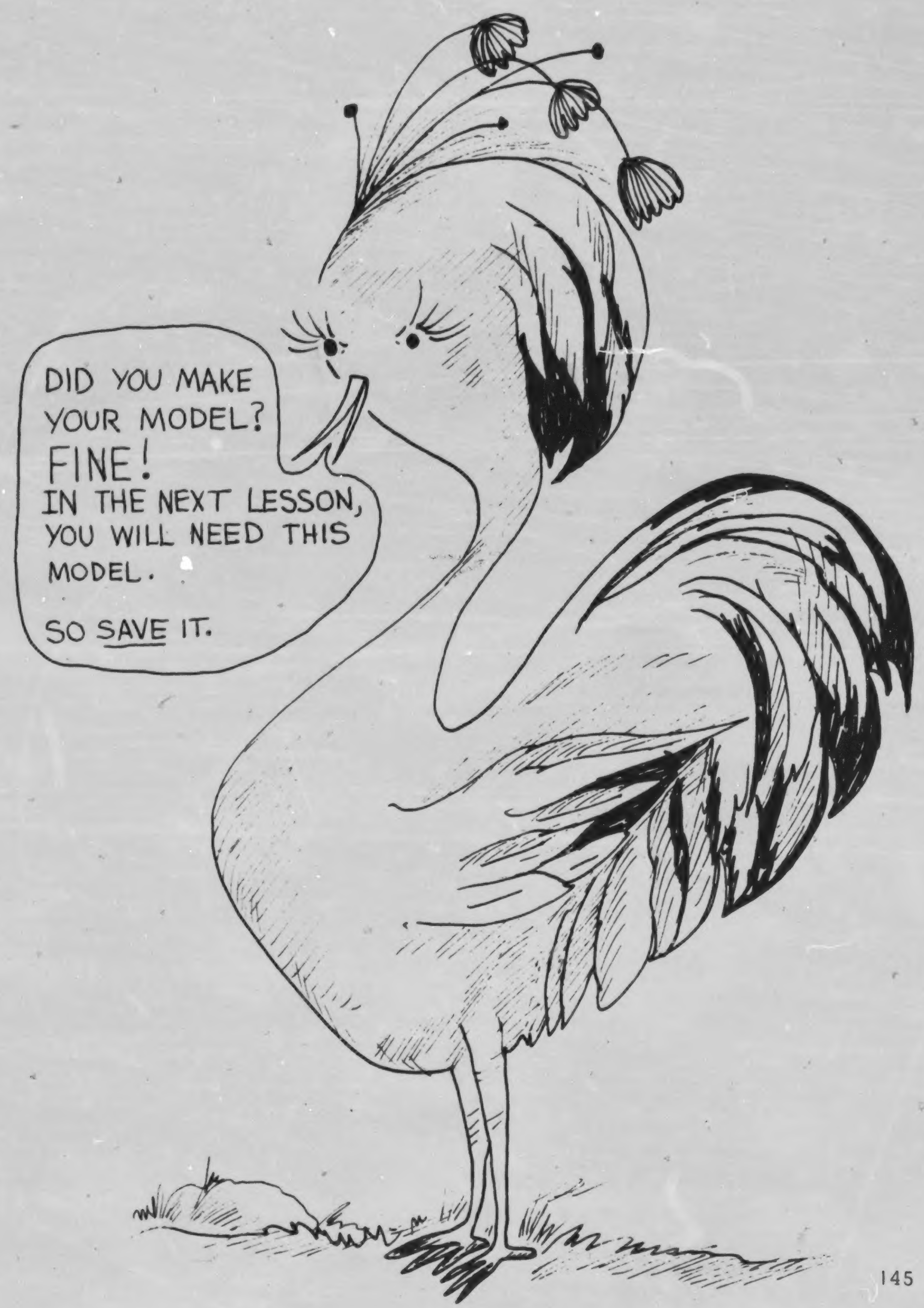
"Perhaps if I gave you a cardboard model of a quartz crystal, with the ends cut off, it would help," Studious said. She gave him a model she had made for herself.


WHY DON'T YOU MAKE A MODEL? ALL YOU HAVE TO DO IS TEAR WORKSHEET 23 FROM YOUR STUDENT MANUAL CAREFULLY. THEN CUT AROUND THE HEAVY BLACK LINE, AND FOLD ON THE DOTTED LINES. TAPE THE OPEN SIDE TOGETHER. THEN TAPE EACH END. NOW YOU HAVE A MODEL OF A QUARTZ CRYSTAL WITH THE ENDS CUT OFF.
HE ALWAYS HAS A LOT TO SAY.

Worksheet 23
Unit 26

Name______________________




DID YOU MAKE YOUR MODEL? FINE! IN THE NEXT LESSON, YOU WILL NEED THIS MODEL. SO SAVE IT.

Lesson 14: EXAMINING THE SHAPE OF CORUNDUM CRYSTALS

In this lesson the children learn that there are six basic crystal shapes. They will recognize that table salt crystals are of a cubic shape and that quartz crystals are of a hexagonal shape.

Next the children will observe that corundum crystals are also of a hexagonal shape. You can demonstrate the hexagonal shape of both quartz and corundum crystals by placing them upright on an overhead projector and having the children count the sides.

A continuation of the story started in Lesson 13 provides the teaching device for the lesson. As before, each time a question is raised, stop reading the story and give the children an opportunity to make their own observations and discoveries before Super-Sleuth makes his.

MATERIALS

- Part 2 of Super-Sleuth story (provided in this lesson and in the Student Manuals)
- 8 quartz and 8 corundum crystals
- cardboard models of basic hexagonal shape from previous lesson
- overhead projector
- paper, pencil

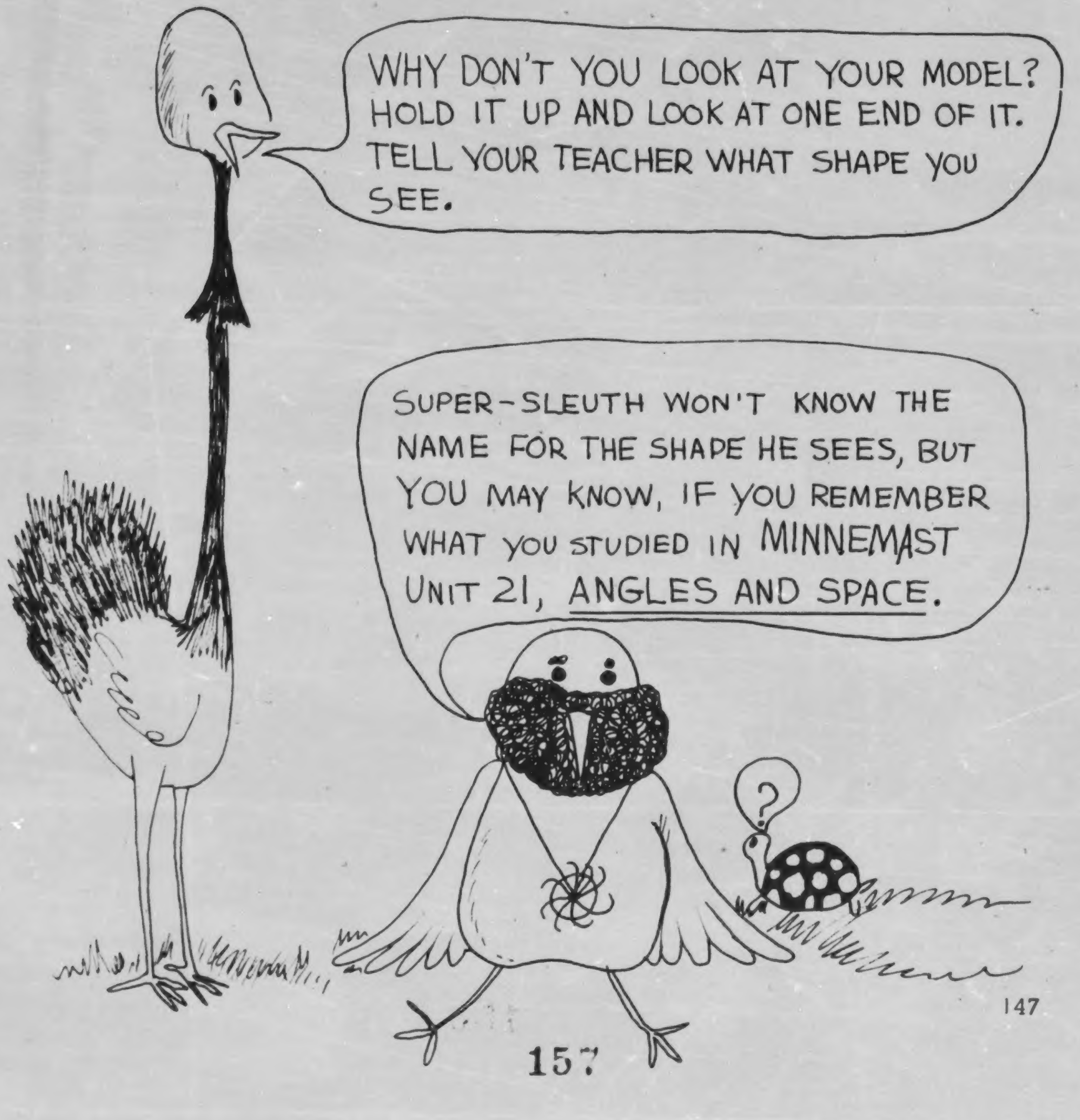
PROCEDURE

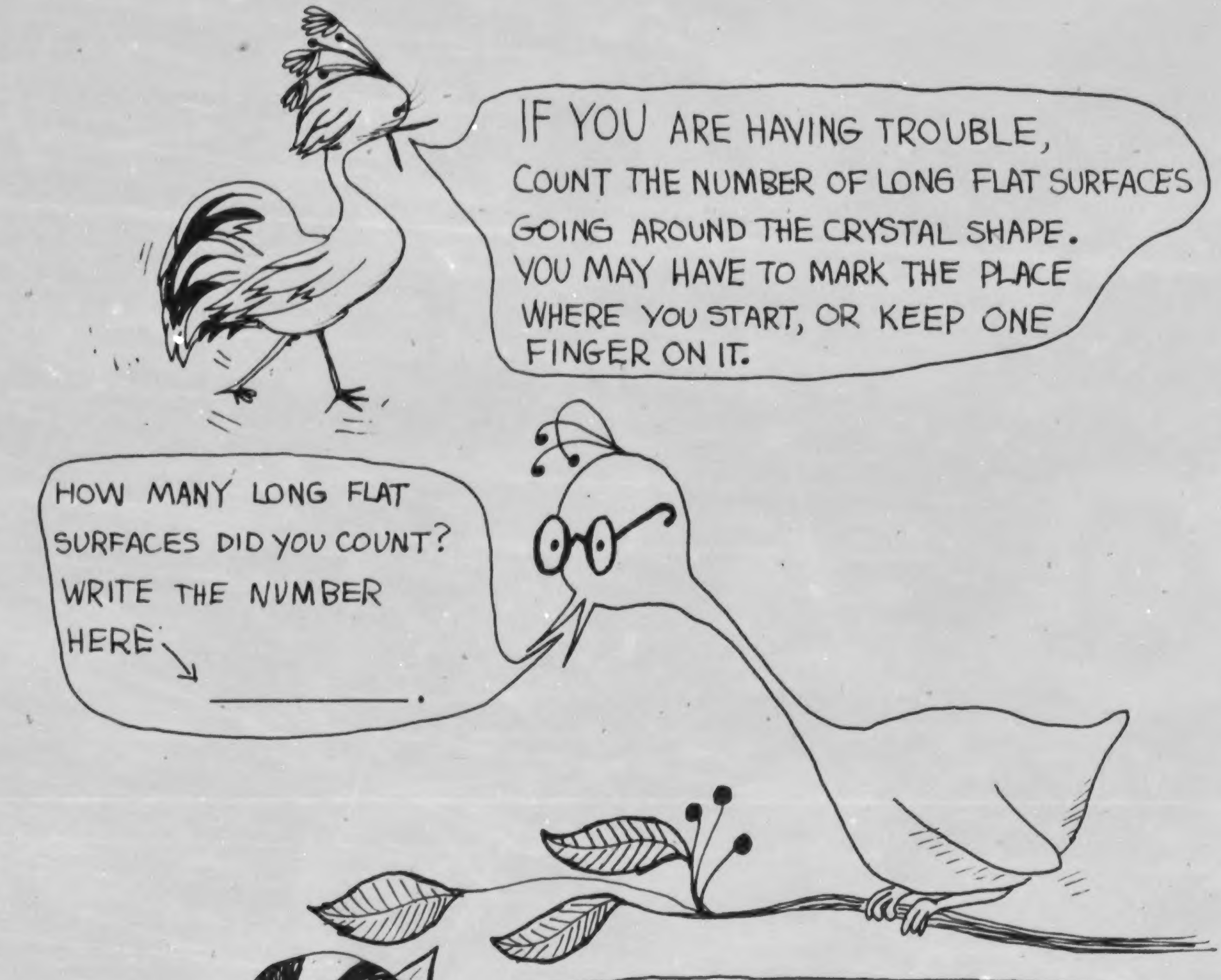
Have the eight quartz and the eight corundum crystal samples handy on a demonstration table in a clear area of the room. If possible, have an overhead projector ready for use also. Ask the children to bring their hexagonal cardboard models, a pencil, and their Student Manuals to the clear area. Have them sit down and ask them to turn to part two of the Super-Sleuth story. Start reading the story as the children follow along in their own books. Stop whenever a question is posed in the story and have the children try to answer it.

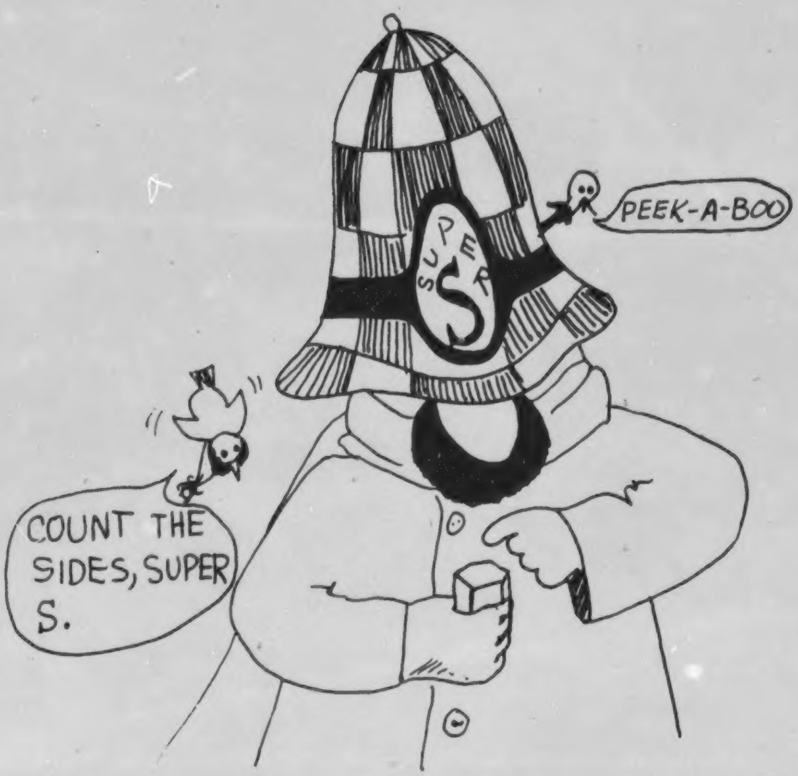
SUPER-SLEUTH AND STUDIOUS JONES

Part 2

Super-Sleuth started to study the cardboard model of the quartz crystal. Studious asked him to hold it up and look at one end of it. "What shape do you see?" she asked.


WHY DON'T YOU LOOK AT YOUR MODEL? HOLD IT UP AND LOOK AT ONE END OF IT. TELL YOUR TEACHER WHAT SHAPE YOU SEE.
SUPER-SLEUTH WON'T KNOW THE NAME FOR THE SHAPE HE SEES, BUT YOU MAY KNOW, IF YOU REMEMBER WHAT YOU STUDIED IN MINNEMAST UNIT 21, ANGLES AND SPACE.
?


IF YOU ARE HAVING TROUBLE, COUNT THE NUMBER OF LONG FLAT SURFACES GOING AROUND THE CRYSTAL SHAPE. YOU MAY HAVE TO MARK THE PLACE WHERE YOU START, OR KEEP ONE FINGER ON IT.
HOW MANY LONG FLAT SURFACES DID YOU COUNT? WRITE THE NUMBER HERE ↘ ________.
WHAT DO YOU CALL A FIGURE WITH THAT NUMBER OF SIDES? ________. IF YOU DON'T REMEMBER, DON'T WORRY. STUDIOUS WILL HAVE TO TELL SUPER-SLEUTH THE NAME, TOO.


PEEK-A-BOO
SUPER
S
COUNT THE SIDES, SUPER S.

When Super-Sleuth finished looking at the model of the quartz crystal, he said, "This model has a lot of long, flat surfaces, doesn't it?"

"How many?" Studious asked.

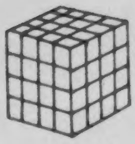
"Well, I will have to count," Super-Sleuth said. He counted around the long flat surfaces and said, "This model of a quartz crystal has six long flat surfaces."

"Correct," Studious said. "A shape that has six flat surfaces arranged like this has a special name. Do you know what it is? It is called a hexagonal shape."

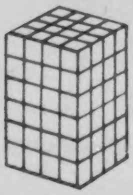
"Now I have discovered two different crystal shapes -- the cubic and the hexagonal. Are there any more kinds of crystal shapes, Studious?" Super-Sleuth asked.

Studious reached in her bag and brought out another book. "Years ago," she said, "scientists divided the set of all crystal shapes into subsets of shapes that they call the six basic crystal shapes." Studious opened the book. "Look here, Super-Sleuth," she said.

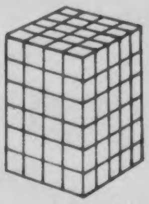
Super-Sleuth looked at the page. It showed the six basic crystal shapes, and their names, like this:



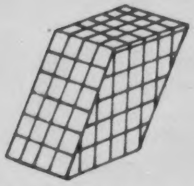
Cubic



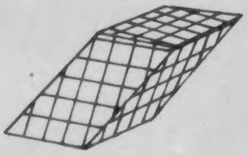
Tetragonal



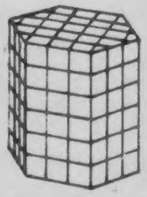
Orthorhombic



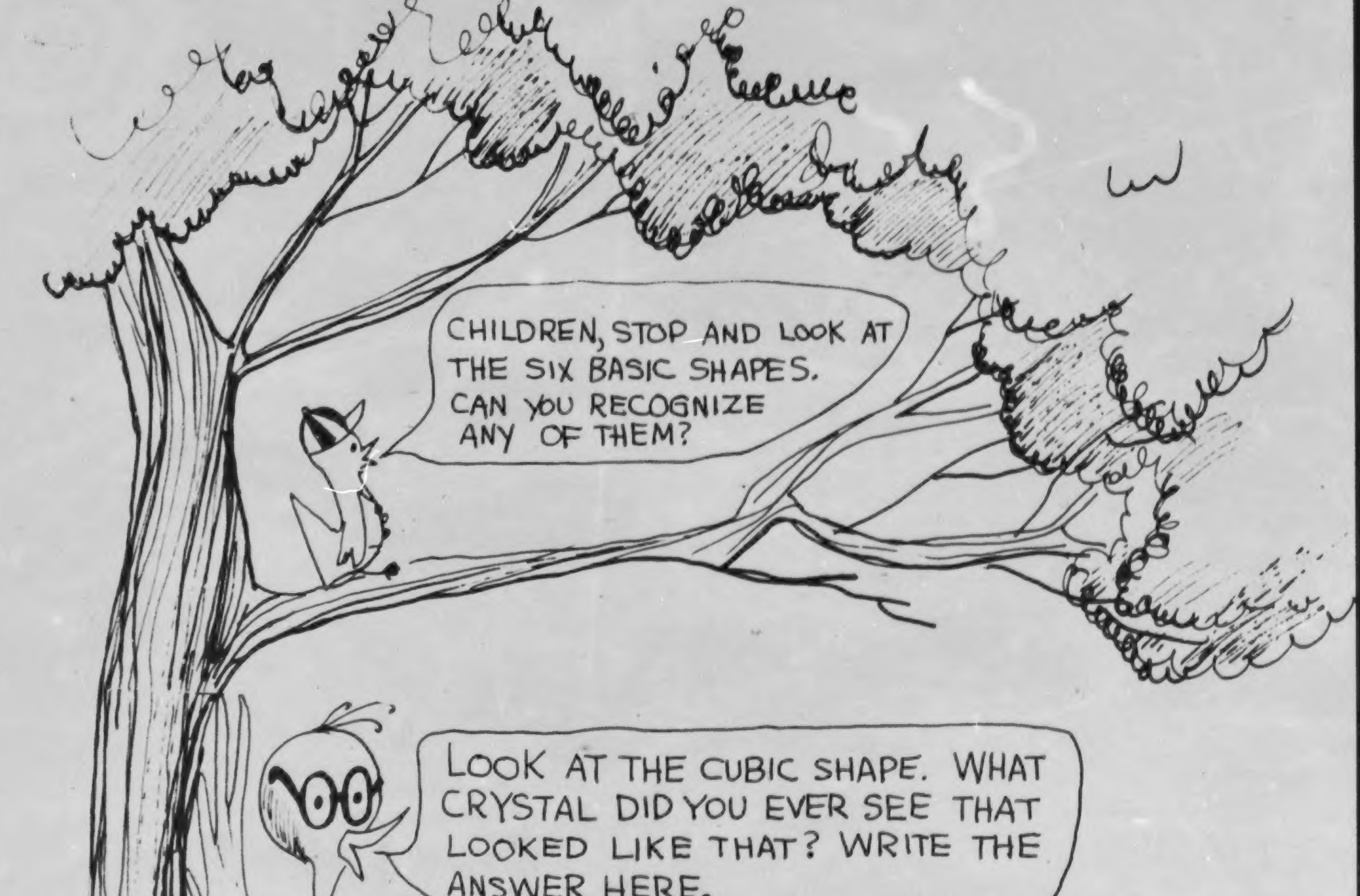
Monoclinic



Triclinic



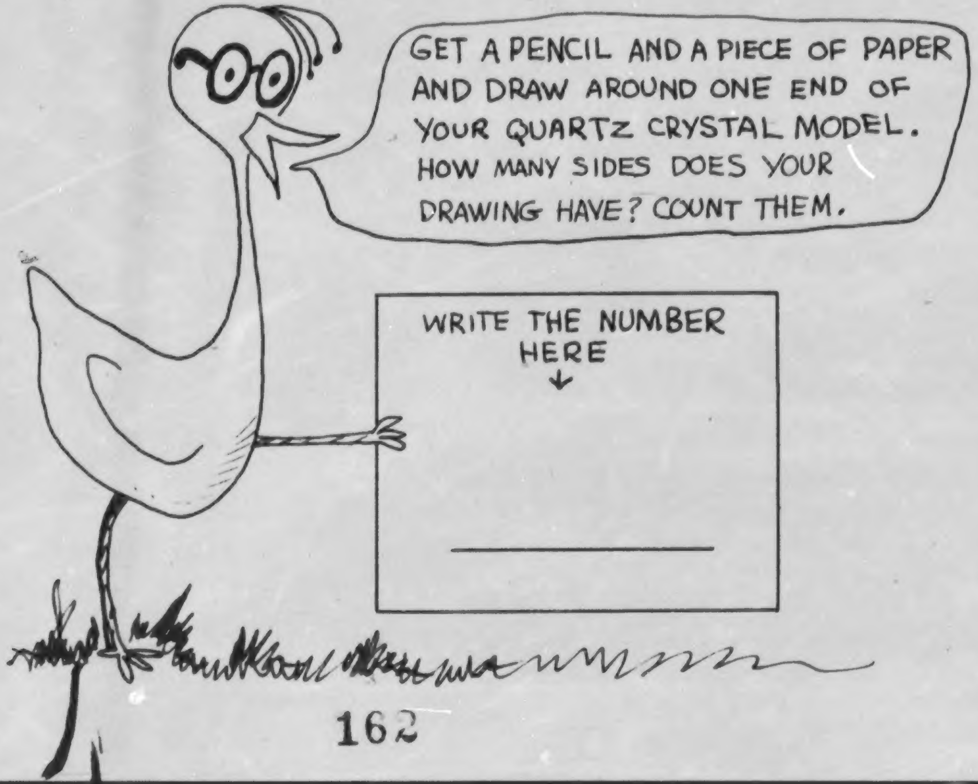
Hexagonal

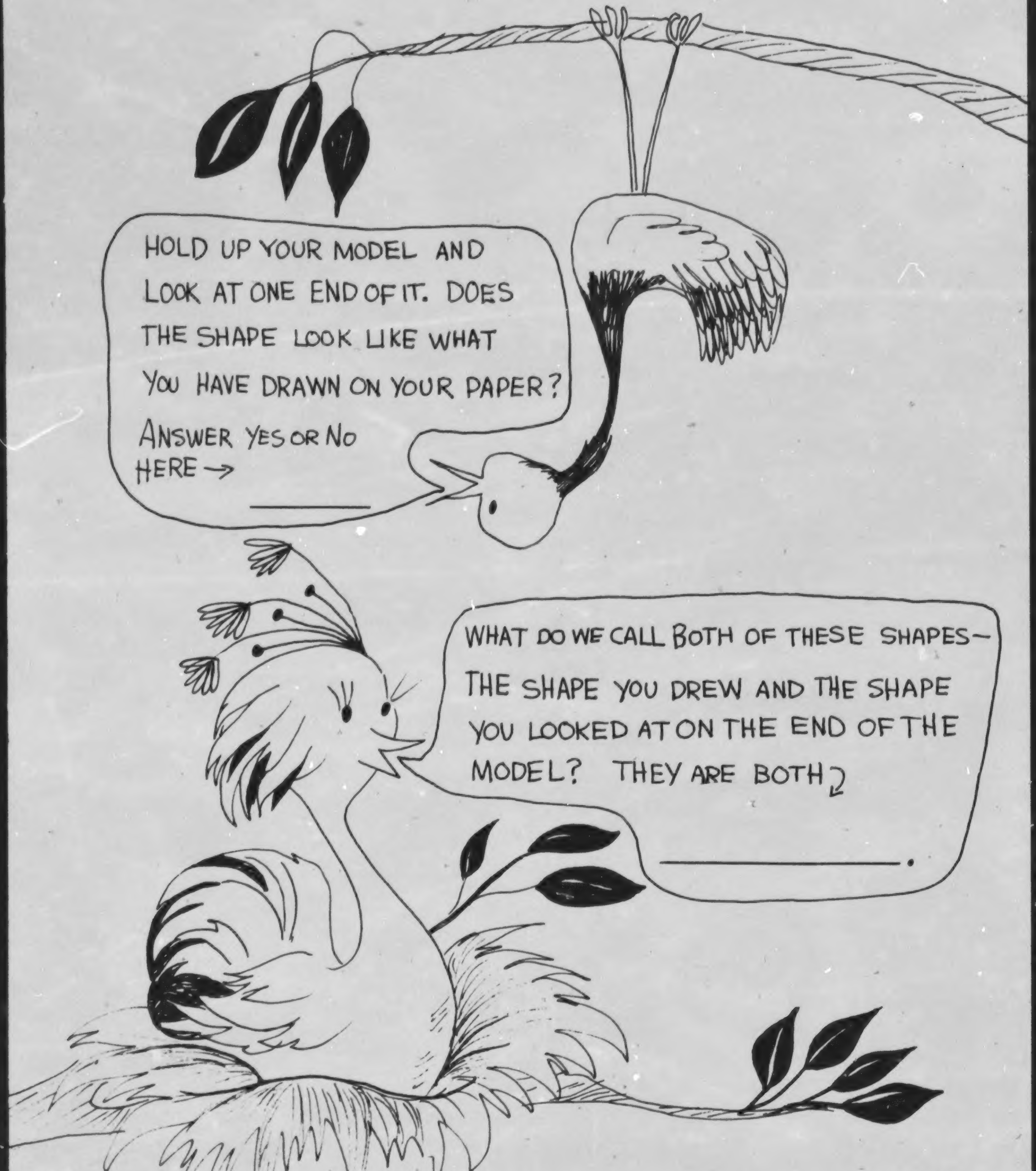

CHILDREN, STOP AND LOOK AT THE SIX BASIC SHAPES. CAN YOU RECOGNIZE ANY OF THEM?
LOOK AT THE CUBIC SHAPE. WHAT CRYSTAL DID YOU EVER SEE THAT LOOKED LIKE THAT? WRITE THE ANSWER HERE. ____________.
LOOK AT THE HEXAGONAL SHAPE. IF YOU CAN REMEMBER CRYSTALS THAT HAVE THAT SHAPE, WRITE THE NAMES HERE: ____________ ____________
HE TOOK A GIANT STEP!

Super-Sleuth studied the six basic shapes. He pointed to the cubic shape and said, "Hey, Studious, that is the shape of table salt." Then he pointed to the hexagonal shape and said, "And this is the shape of a quartz crystal."

Studious was very pleased. "Why don't you come home with me, Super-Sleuth, so we can learn some more about crystal shapes? My mother will give us cookies and milk, and we can sit at the table and enjoy ourselves."

"That's a fine idea," Super-Sleuth said, and that is just what they did. While they were sitting at the table, Studious asked Super-Sleuth to place one end of his hexagonal quartz model on a piece of paper and draw a line around it. She asked him to look at what he had drawn and to count the sides. Then she asked him to pick up a quartz crystal and hold one end of it up in front of his eyes, and see if the shape on the paper and the shape of the crystal looked similar.

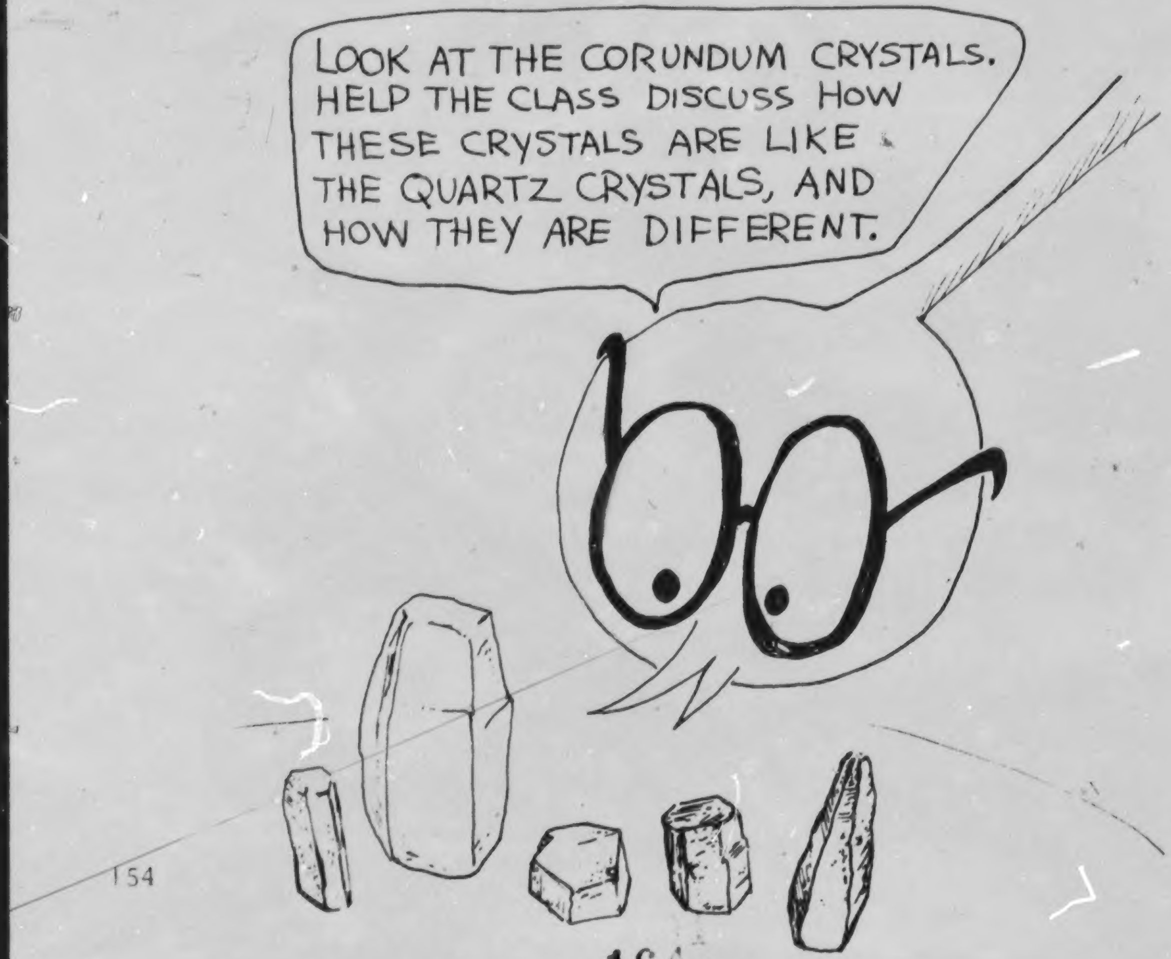

GET A PENCIL AND A PIECE OF PAPER AND DRAW AROUND ONE END OF YOUR QUARTZ CRYSTAL MODEL. HOW MANY SIDES DOES YOUR DRAWING HAVE? COUNT THEM.
WRITE THE NUMBER HERE ↓


HOLD UP YOUR MODEL AND LOOK AT ONE END OF IT. DOES THE SHAPE LOOK LIKE WHAT YOU HAVE DRAWN ON YOUR PAPER? ANSWER YES OR NO HERE → ______
WHAT DO WE CALL BOTH OF THESE SHAPES— THE SHAPE YOU DREW AND THE SHAPE YOU LOOKED AT ON THE END OF THE MODEL? THEY ARE BOTH ______.

Super-Sleuth did as he was told, but Studious could see that he was getting bored. He was much more interested in stuffing himself with cookies than in stuffing himself with information about crystal shapes. But Studious had a surprise for him. She brought out some corundum crystals.

"Stars above! What are those?" Super-Sleuth exclaimed.

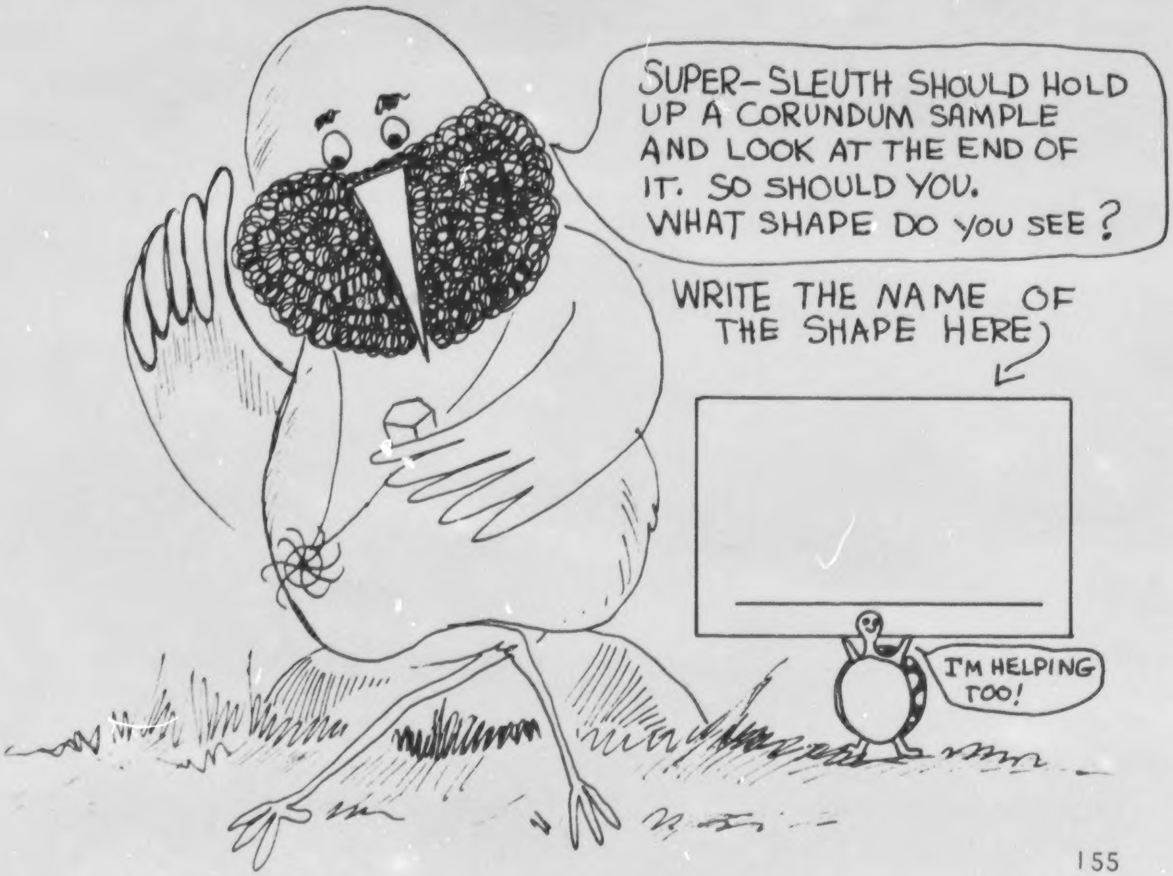
"Corundum crystals," Studious replied. "I want you to study them closely. See if you can discover in what way they might be like the quartz crystals."


LOOK AT THE CORUNDUM CRYSTALS. HELP THE CLASS DISCUSS HOW THESE CRYSTALS ARE LIKE THE QUARTZ CRYSTALS, AND HOW THEY ARE DIFFERENT.

Super-Sleuth said, "I can see plenty of ways in which these crystals are different from the quartz, but I can't see any way in which they are like the quartz."

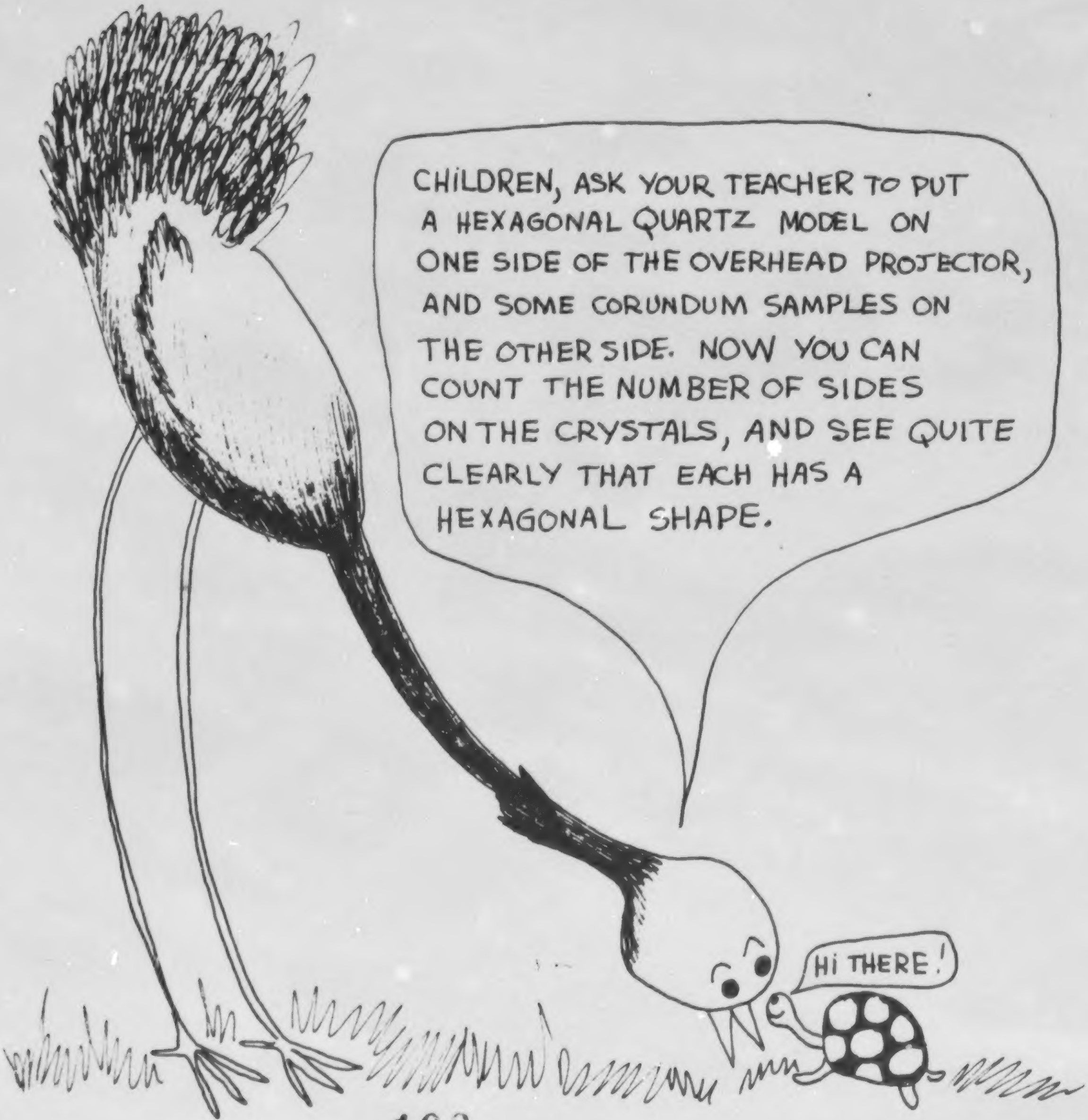
"Observe them closely," Studious said, "and perhaps you will find a resemblance. After all, we don't call you Super-Sleuth for nothing."

"Of course not," Super-Sleuth said. "If there is anything similar about these co-run-dum crystals and the quartz crystals, I'll be the first person in the world to find out."


SUPER-SLEUTH SHOULD HOLD UP A CORUNDUM SAMPLE AND LOOK AT THE END OF IT. SO SHOULD YOU. WHAT SHAPE DO YOU SEE?
WRITE THE NAME OF THE SHAPE HERE
I'M HELPING TOO!

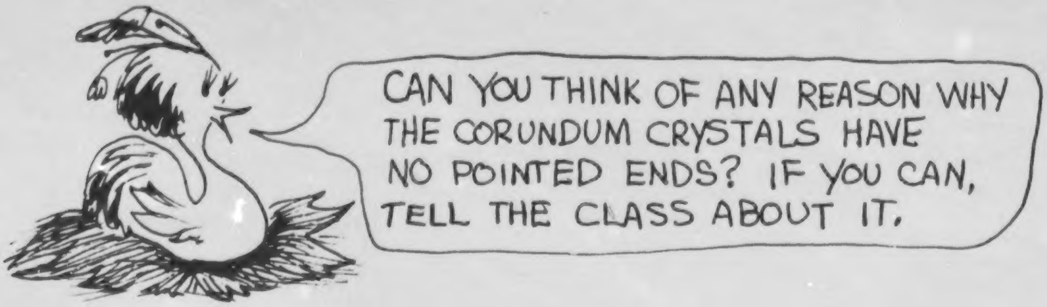
"A-ha!" Super-Sleuth said. "I have discovered a great secret. Looking at the ends, the co-run-dum crystals are the same shape as the quartz crystals. They both have hexagonal shapes."

"Yes, they do," Studious said. "If we had an overhead projector, we could use it to check this fact."


CHILDREN, ASK YOUR TEACHER TO PUT A HEXAGONAL QUARTZ MODEL ON ONE SIDE OF THE OVERHEAD PROJECTOR, AND SOME CORUNDUM SAMPLES ON THE OTHER SIDE. NOW YOU CAN COUNT THE NUMBER OF SIDES ON THE CRYSTALS, AND SEE QUITE CLEARLY THAT EACH HAS A HEXAGONAL SHAPE.
HI THERE!

Studious noticed that Super-Sleuth was still looking at the quartz and corundum crystals, as if he still wanted to know more about them. He said, "Even though the quartz and co-run-dum crystals both have hexagonal shapes, there's still something very different about them. Tell me, Studious, do the co-run-dum crystals grow in clusters like the quartz? If they do, how come they have two rough ends, but no points on any end?"

"That's a very good question, Super-Sleuth. Can you find the answer yourself?"


CAN YOU THINK OF ANY REASON WHY THE CORUNDUM CRYSTALS HAVE NO POINTED ENDS? IF YOU CAN, TELL THE CLASS ABOUT IT.

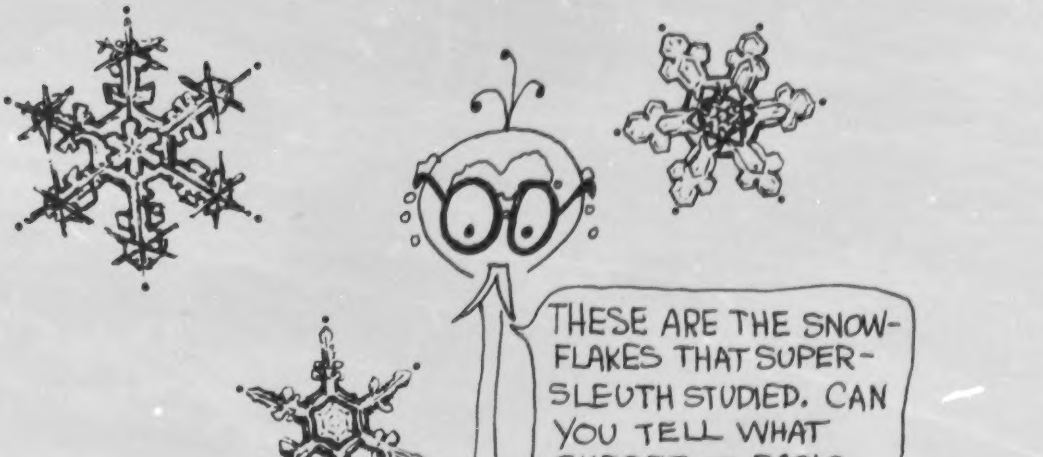
Super-Sleuth really strained his brain trying to think. Studious went to the kitchen and brought in a plate of chocolate-chip cookies. Super-Sleuth took one look at the cookies and said, "That's it!"

"What's what?" Studious asked. She knew that Super-Sleuth must be on the track of something very interesting, if he would just stare at the cookies instead of eating them.

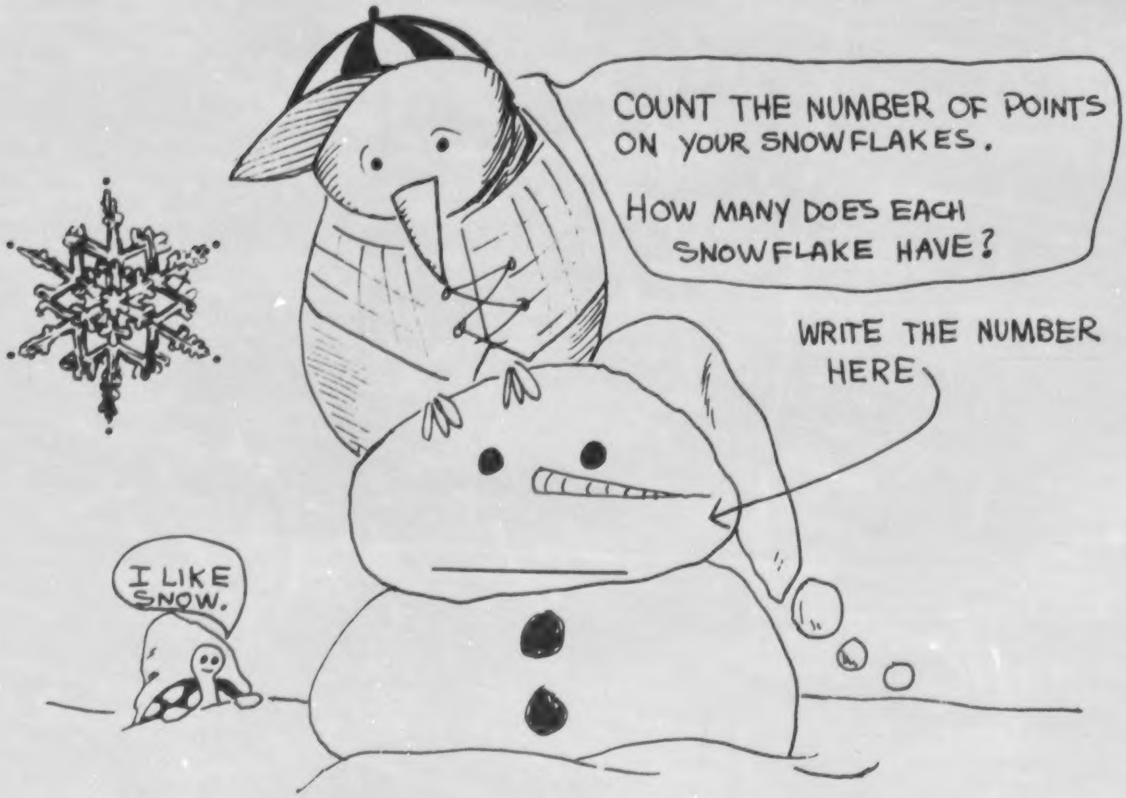
"Studious, I have decided that these corundum crystals come like the chocolate chips in those cookies -- not in clusters or bunches but here and there in some other material."

"You're absolutely right, Super-Sleuth. The corundum crystals form separately -- one by one -- in a big mass of brown or black material that is called 'lava.' Geologists have to chop away the other material in order to find the crystals that are scattered through it."

Super-Sleuth thought that, by now, he must be the world's greatest expert on crystal shapes. He was ready to take his birds and go home. But Studious Jones had other ideas. She showed him a page of snowflake pictures, and asked him if he could decide which basic crystal shape the snowflakes had. Super-Sleuth got out his magnifying glass and studied the snowflakes.


THESE ARE THE SNOWFLAKES THAT SUPER-SLEUTH STUDIED. CAN YOU TELL WHAT SUBSET OF BASIC CRYSTAL SHAPES THEY BELONG TO?
SNOW LOOKS LIKE THIS?

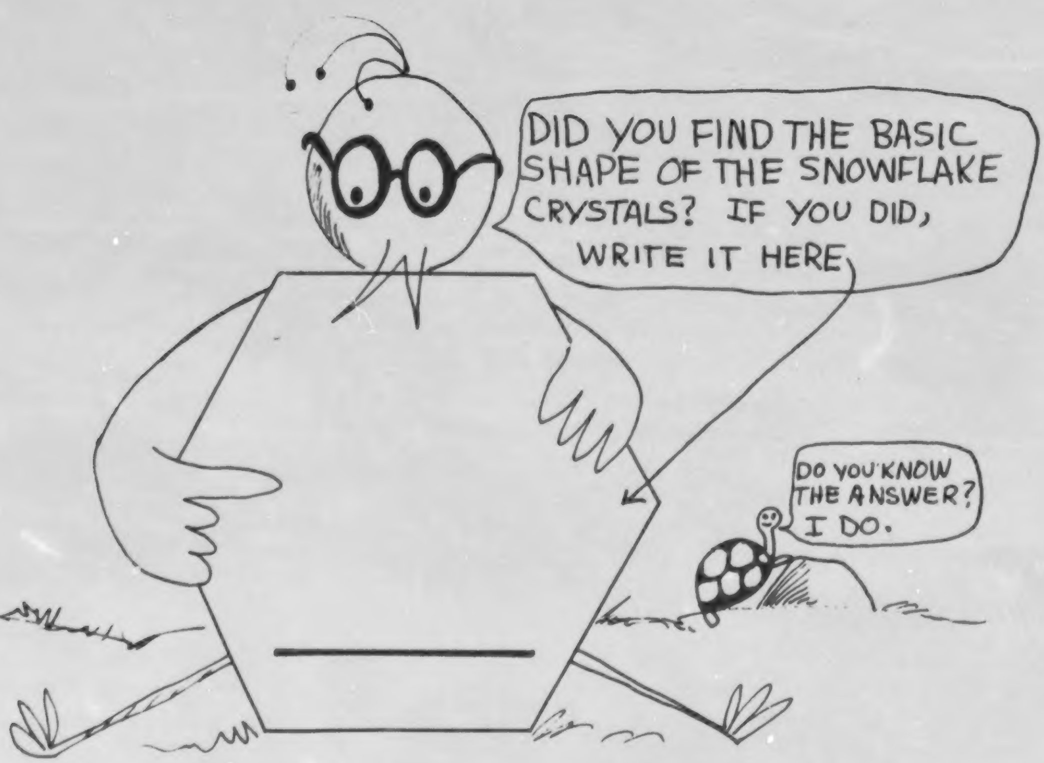
Super-Sleuth counted the points of each snowflake. Surprisingly, the number of points was always the same.


COUNT THE NUMBER OF POINTS ON YOUR SNOWFLAKES.
HOW MANY DOES EACH SNOWFLAKE HAVE?
WRITE THE NUMBER HERE
I LIKE SNOW.

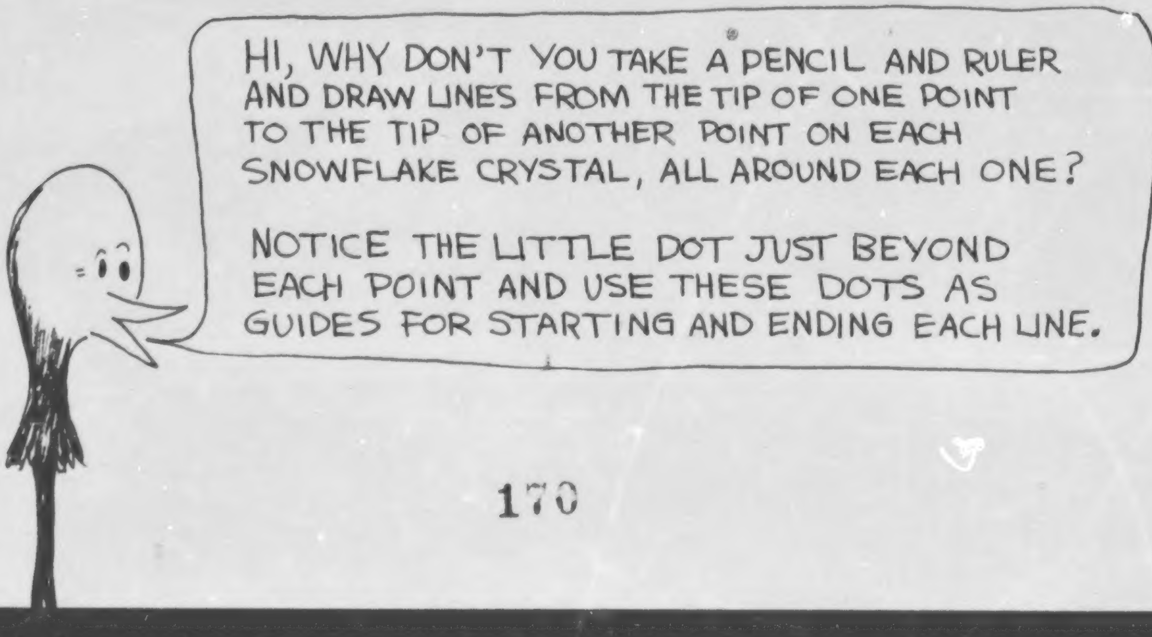
"I've counted the number of points on each snowflake," Super-Sleuth said, "and they all have the same number. But what does that prove about their shape?"

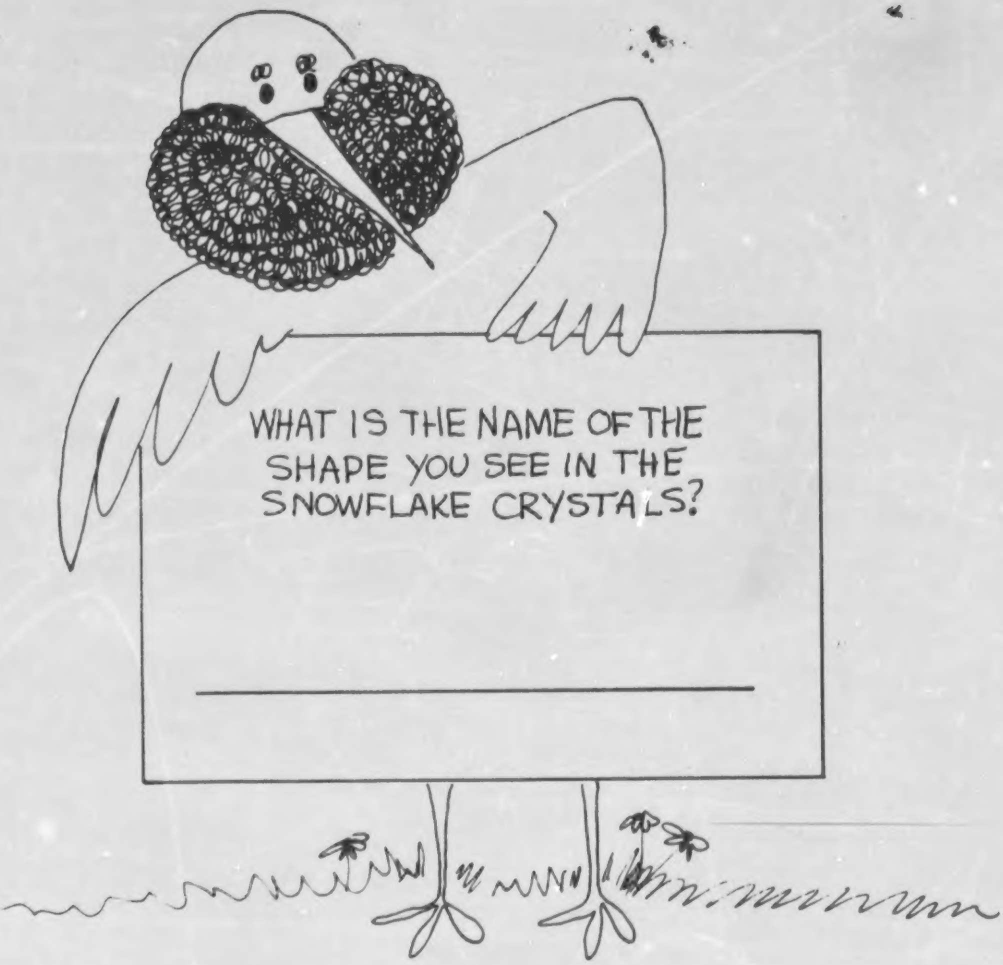
"Not much," Studious said. "But if you look more toward the center of the crystals, maybe you could see a typical shape."

"A-ha. I do," Super-Sleuth said, and he told Studious the correct basic shape that he saw in each crystal.


DID YOU FIND THE BASIC SHAPE OF THE SNOWFLAKE CRYSTALS? IF YOU DID, WRITE IT HERE
DO YOU KNOW THE ANSWER? I DO.

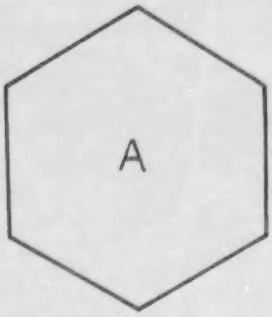
"Another thing you could do, Super-Sleuth, would be to take a pencil and ruler and draw lines from the tip of each point on a snowflake to the tip of the next point, and so on around the crystal until you had all the sides drawn." Super-Sleuth took a pencil and a ruler and did this.

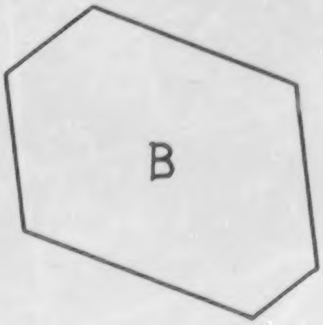

HI, WHY DON'T YOU TAKE A PENCIL AND RULER AND DRAW LINES FROM THE TIP OF ONE POINT TO THE TIP OF ANOTHER POINT ON EACH SNOWFLAKE CRYSTAL, ALL AROUND EACH ONE?
NOTICE THE LITTLE DOT JUST BEYOND EACH POINT AND USE THESE DOTS AS GUIDES FOR STARTING AND ENDING EACH LINE.


WHAT IS THE NAME OF THE SHAPE YOU SEE IN THE SNOWFLAKE CRYSTALS?

Super-Sleuth was able to give the correct answer, too. Now he started to say goodbye again, but again Studious stopped him. This time she drew two figures on a piece of paper, marked them A and B, and asked Super-Sleuth to look at them.

HERE IS WHAT STUDIOUS DREW ON THE PAPER FOR SUPER-SLEUTH.





Studious asked, "What is alike about these two figures?"

WHAT DO YOU THINK IS ALIKE ABOUT THE TWO FIGURES?
I'M OUT ON A LIMB.

Super-Sleuth said, "I don't think the figures look much alike at all." Studious gave him a hint, saying, "Why don't you try counting the number of sides on each figure?" Super-Sleuth did that.

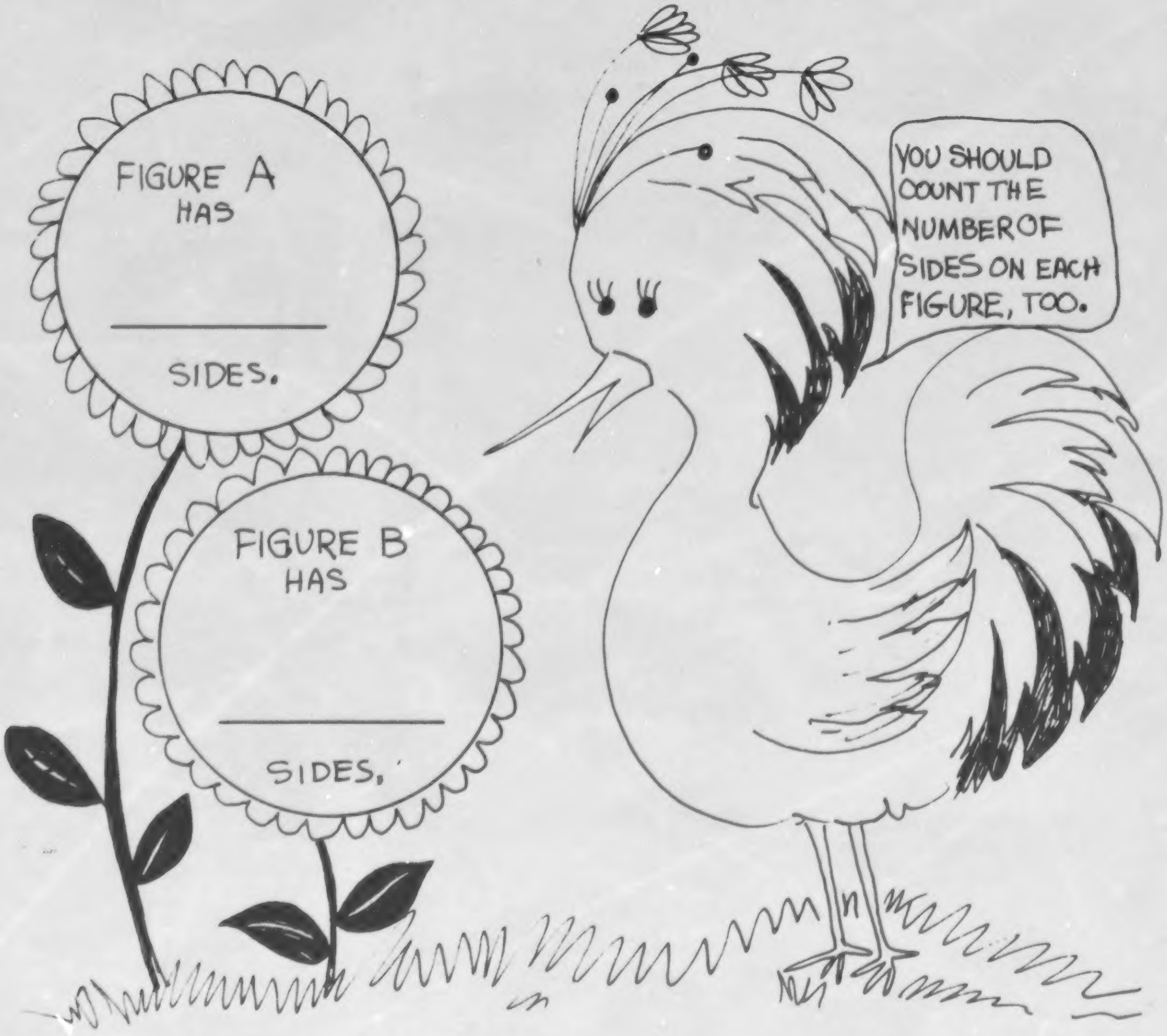


FIGURE A HAS
____
SIDES.
FIGURE B HAS
____
SIDES.
YOU SHOULD COUNT THE NUMBER OF SIDES ON EACH FIGURE, TOO.

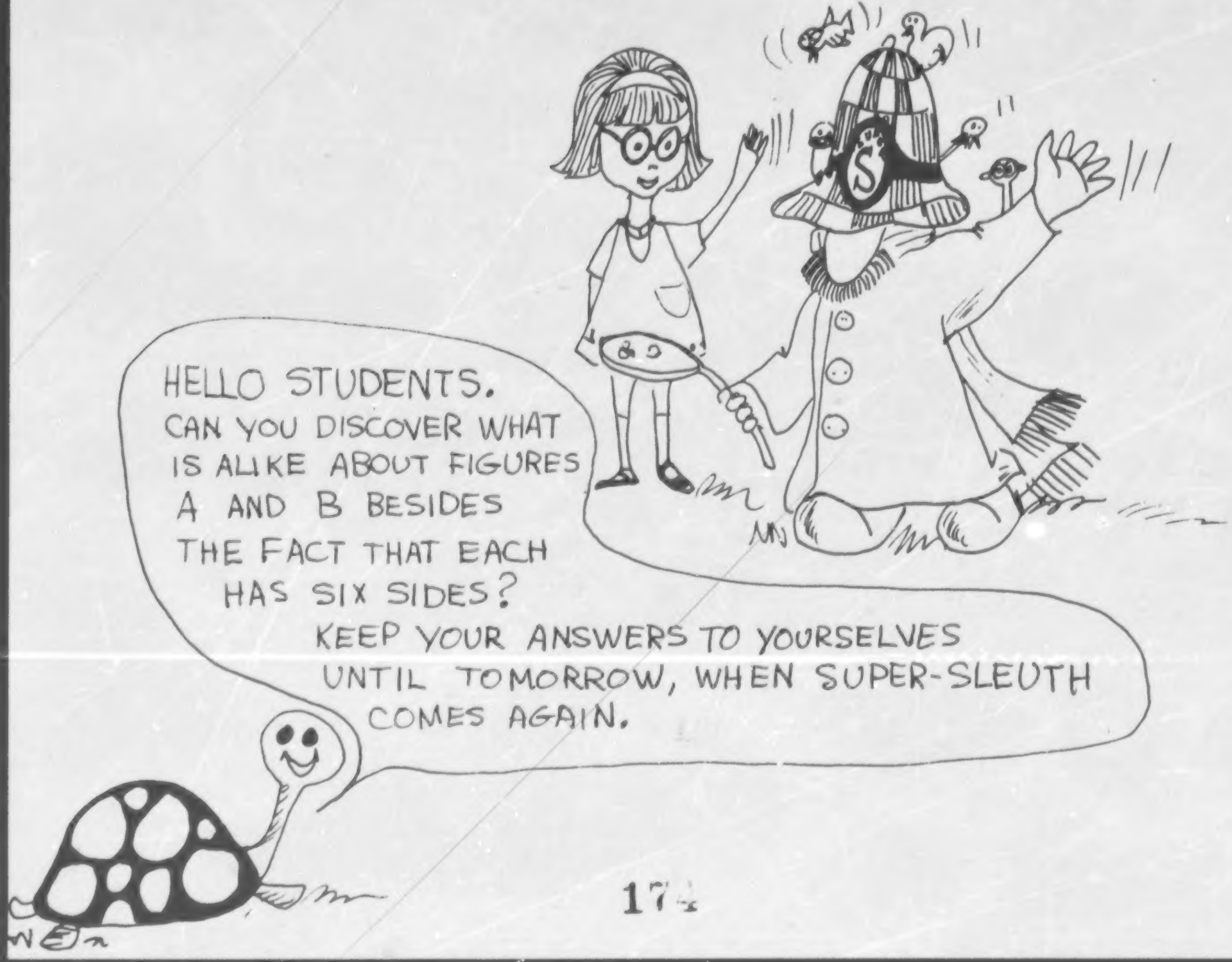
Super-Sleuth counted the number of sides on each figure correctly. "Now, surely, it is time to go home," he said.

"Not quite," Studious said. "You have counted the sides on each figure, and found that each has six sides. That means that both figures are hexagonal in shape. But there is something else that is alike about the two figures. Can you tell me what it is, Super-Sleuth?"

Super-Sleuth stared at the figures a long time. He didn't want Studious to know that his brains were completely frazzled from so much thinking, so he said, "Studious, my birds are hungry. I really have to take them home and feed them." At this, the birds fluttered wildly around the room calling out, "Hungry! Hungry! Hungry!"

"All right, Super-Sleuth, maybe you should go home now," Studious said. "But take this paper home with you, and maybe by tomorrow you can figure out what is alike between the two figures, besides the fact that each has six sides."

"Till tomorrow, then," Super-Sleuth said. With his birds roosting all over him, he went home.


S
HELLO STUDENTS. CAN YOU DISCOVER WHAT IS ALIKE ABOUT FIGURES A AND B BESIDES THE FACT THAT EACH HAS SIX SIDES? KEEP YOUR ANSWERS TO YOURSELVES UNTIL TOMORROW, WHEN SUPER-SLEUTH COMES AGAIN.

Lesson 15: ANOTHER CRYSTAL PROPERTY -- MAG OF THE ANGLE

Learning that crystal shapes have characteristic angles provides the children with another property that is valuable in identifying certain materials. If a scientist found a badly damaged crystal of some sort that still had even one unbroken angle with a mag of 120 degrees, he could hypothesize that a typical crystal of this same kind might belong to the basic crystal subset of hexagonal shape. Why would he be able to do this? That is what the children find out in this lesson.

After comparing two hexagonal shapes in the last lesson, the children found out that both figures had six sides each. Now they will discover, by the use of a protractor, that -- even though the lengths of the sides of the two hexagonal shapes are different -- each angle has a mag of 120 degrees.

The transparent protractor used in this lesson and in Lesson 16 is similar to the clock protractor the children used in Unit 21, except that this new one has degrees (180) as well as hours (6).

The lesson begins with the third and last part of the story about Super-Sleuth, then goes on to give the children practice in measuring the mag of angles.

MATERIALS

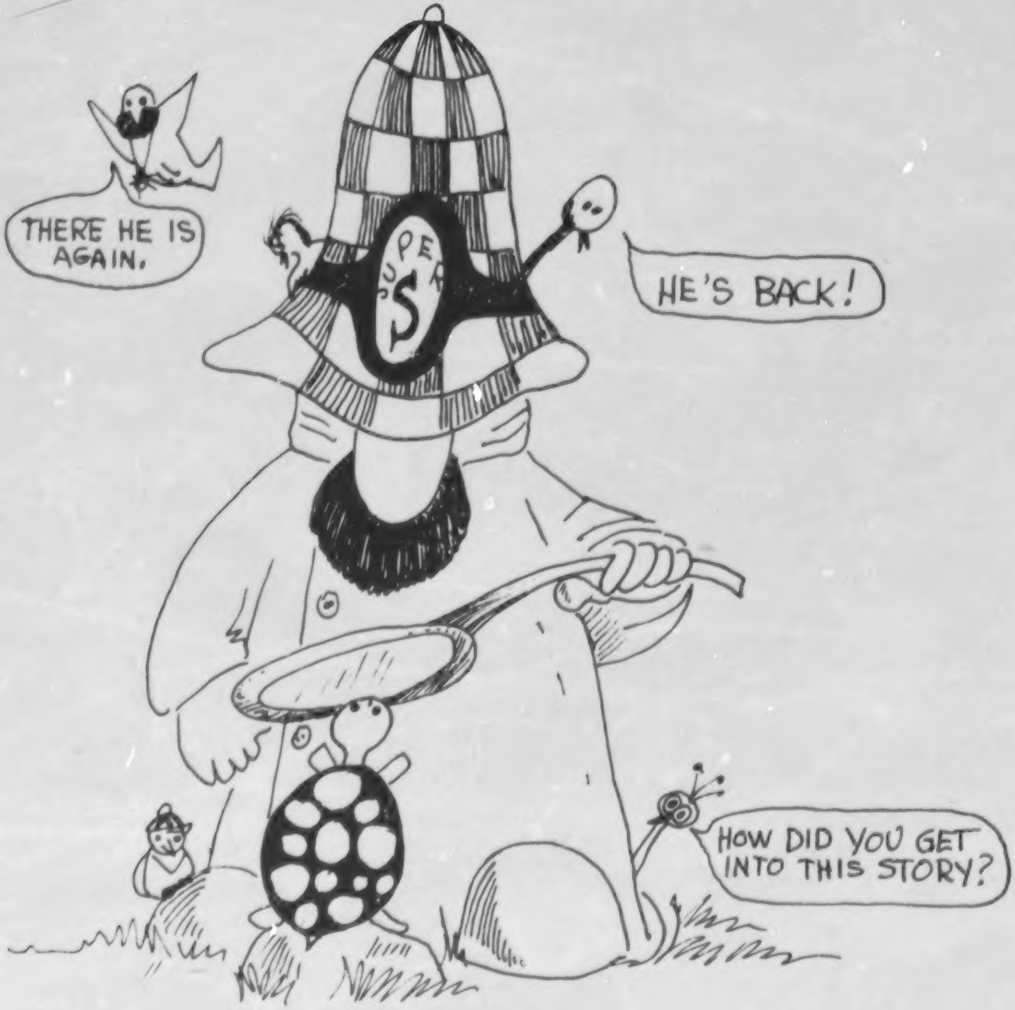
- Part 3 of Super-Sleuth story provided in this lesson and in the Student Manuals
- Worksheets 24 through 27
- protractor on transparency, 1 per child

PREPARATION

The transparent protractors used in this lesson come with the special printed MINNEMAST materials. Each transparency should be cut in two before class, so that each child can be given one protractor. At the end of the unit, collect the protractors and save them for other MINNEMAST units.

PROCEDURE

The children should remain in their seats as you begin the lesson by reading the concluding part of the Super-Sleuth story. They should follow along in their Student Manuals.

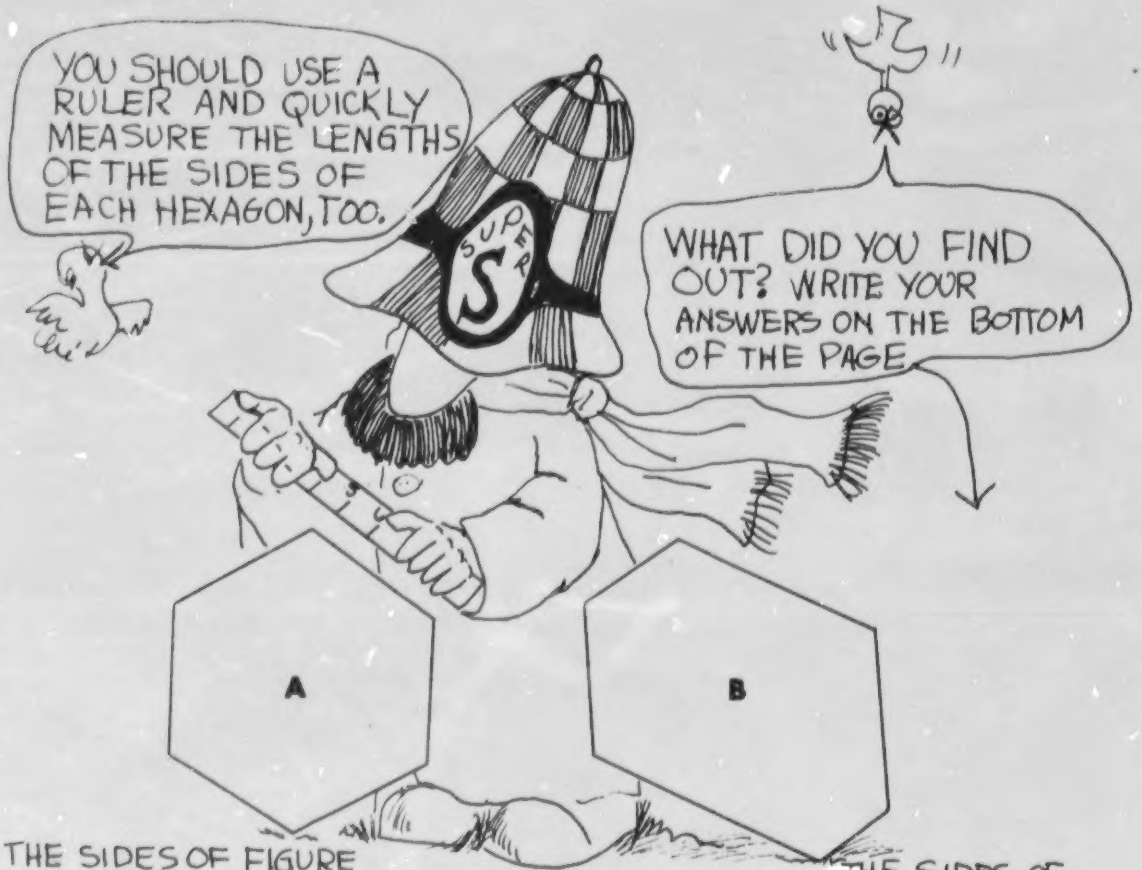

THERE HE IS AGAIN.
SUPER S
HE'S BACK!
HOW DID YOU GET INTO THIS STORY?

SUPER-SLEUTH and STUDIOUS JONES

PART III

SUPER-SLEUTH AND STUDIOUS JONES
Part 3

Super-Sleuth and his birds met Studious Jones the next day on her way home from school. Super-Sleuth had the paper with the two hexagons on it in his hand. He had a big smile on his face as he walked up to her. "I have discovered another difference between these two hexagons," he said. "I measured the lengths of the sides and they are not the same. Here, take this ruler and check for yourself."


YOU SHOULD USE A RULER AND QUICKLY MEASURE THE LENGTHS OF THE SIDES OF EACH HEXAGON, TOO.
WHAT DID YOU FIND OUT? WRITE YOUR ANSWERS ON THE BOTTOM OF THE PAGE.
SUPER
S
A
B

THE SIDES OF FIGURE A ARE ALL ABOUT THE ____________ LENGTH.

THE SIDES OF FIGURE B ARE ALL ____________ LENGTHS.

Studious was not pleased. "Super-Sleuth, I asked you to look for another similarity between the two figures, not a difference. Anyone can see that the figures have sides of different lengths, even though each has six sides. Now, think hard, Super-Sleuth, what else is the same about these two shapes?"

Super-Sleuth really concentrated, but he could not find a single thing more that was alike about the two shapes. He looked so disappointed that Studious decided to give him a hint. She brought out a protractor and handed it to him.

"This thing is full of lines and numerals. What is it for?" Super-Sleuth asked.

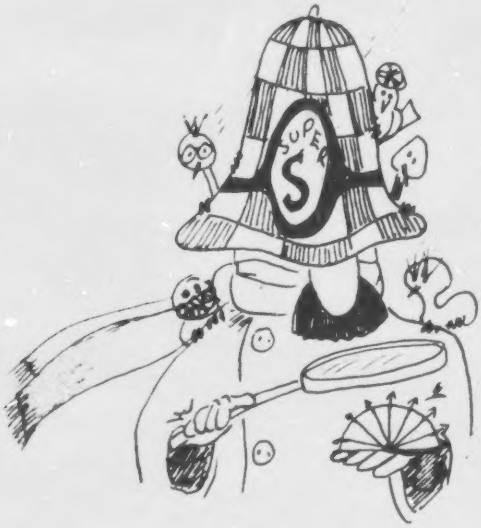
"It's a handy device for measuring the mag of angles," Studious said. "Now, does that give you any clue about what you should be looking for?"

Super-Sleuth turned the protractor over and over in his hands. He looked at it through his trusty magnifying glass. He looked at it near, and he looked at it far. Finally he said, "This fancy thing of yours tells me nothing at all." He sounded rather peevish and his birds settled on his shoulders and hat, as if they felt sorry for him.

"Don't you want to learn how to use the protractor?" Studious asked. "If you would, we could compare the mag of each hexagon's angles to see if they are alike in some way."

Super-Sleuth put his hands on his forehead. His brains felt scrambled. He didn't even know what Studious was talking about. "The mag of angles, indeed!" he thought. "Who ever heard of such a thing?" But out loud, he said, "Studious, I have to hurry home.... I think I left something cooking on the stove. Why don't you just lend the protractor to me for a few days? I'm sure I'll get the hang of it in no time at all."

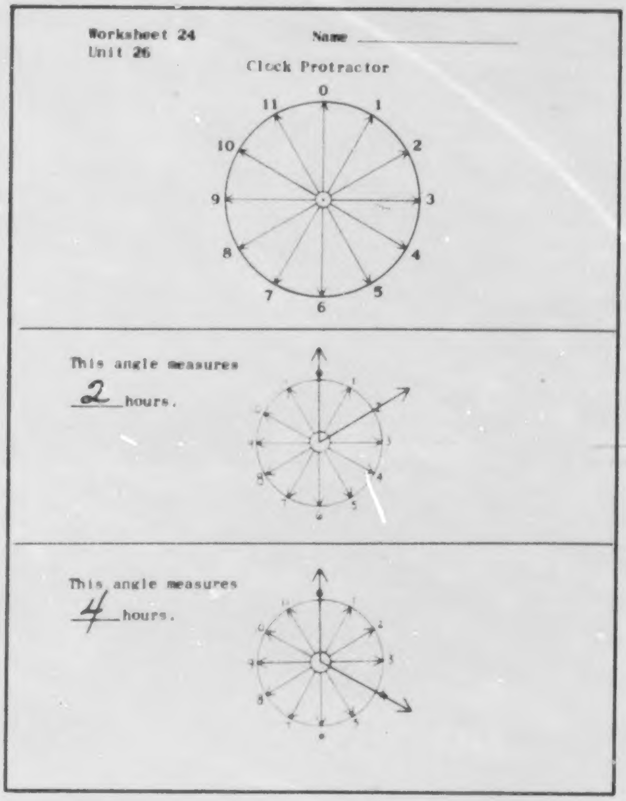
"All right," Studious said, "I have some errands to do, so maybe another day would be better." She gave Super-Sleuth the protractor and said goodbye.



Super-Sleuth hurried away, even though he knew there was nothing cooking on his stove. When he got home, he put the protractor in a drawer and never even tried to figure out how to use it. Instead, he took out a penny and stared at it for a long, long time. He still didn't believe that the copper in the penny was made of crystals. He made up his mind to find a microscope and check what Studious had said. Of course, when he finally got around to doing this, he found out that Studious Jones was right. And he felt bad that a sixth-grade girl knew more than he did about such things. But just think how much worse he would have felt if Studious had told him that children in the second and third grade knew how to use protractors! However, Super-Sleuth still has his friendly birds, and they seem to think he is pretty smart.

SUPER-SLEUTH IS SUPER SMART!
HELLO
LOVE YA! LOVE YA!

Have the children turn to Worksheet 24 which shows a drawing of a clock protractor and some problems. Ask them if they remember using a clock protractor in the second grade when they studied Units 21 and 22. Then briefly review the following angle concepts with your class:



Worksheet 24
Unit 26

Name ________________

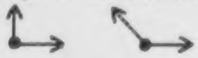
Clock Protractor

This angle measures 2 hours.

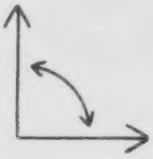
This angle measures 4 hours.

0
1
2
3
4
5
6
7
8
9
10
11

1. A ray is a set of points that has one end point (origin) and extends endlessly in one direction. A ray is represented in this way: •⟶

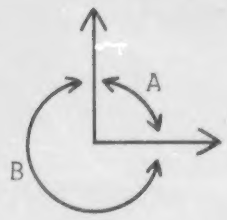
2. An angle is defined as two rays with a common origin (starting point). It is represented like this: 

3. When the children measure a line segment, they are measuring its length. When they measure the amount of space occupied, they are measuring volume. But when they measure an angle, what are they measuring? There was no word for this, so in Unit 21, a word was made up and introduced. The word is "mag." Therefore, when the children measure an angle, they will be measuring its mag. They will do this by measuring the amount of rotation from one ray to the other ray.

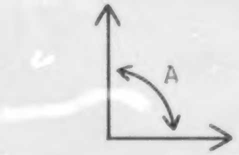


Amount of rotation = Mag of the angle

4. An angle can have different mags.

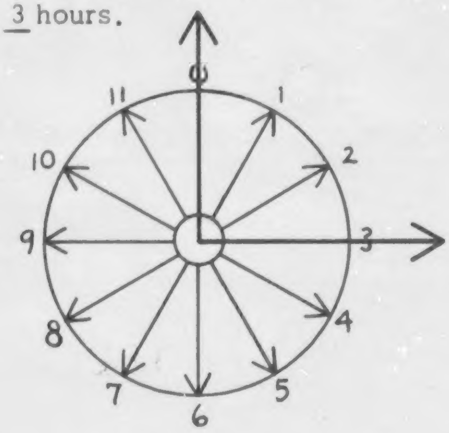


Rotation A is less than rotation B. The angle (made by two rays) does not change at all, but it is possible to rotate in many ways from one ray to another. To avoid confusion in Unit 21, the children were asked to use the smallest mag of an angle, rotation A.



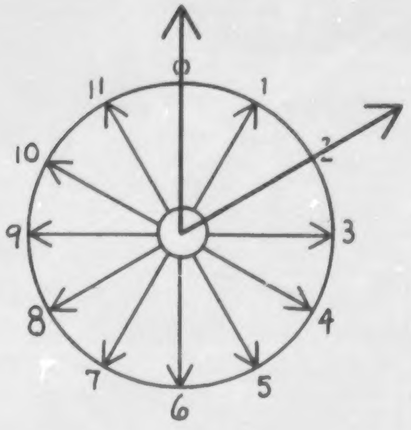
5. To measure the amount of rotation from one ray to the other (the mag of the angle) they used a clock protractor.

6. The unit of measure in Unit 21 was hours. Therefore this angle = 3 hours.

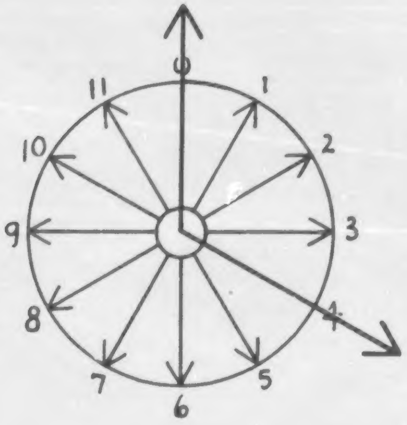


The following two problems are given on the bottom half of Worksheet 24. Have the children write in their answers, then review the process as a class activity.

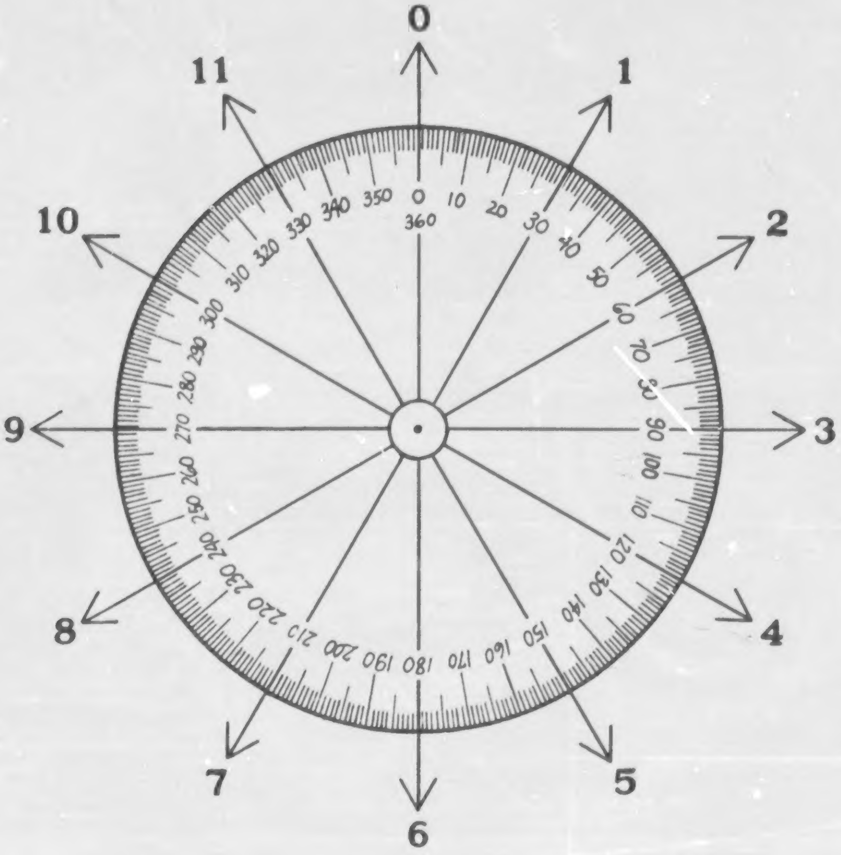
This angle measures 2 hours.


0
1
2
3
4
5
6
7
8
9
10
11

This angle measures 4 hours.


0
1
2
3
4
5
6
7
8
9
10
11

Now tell the children that many years ago, someone divided a circle into 360 equal parts.

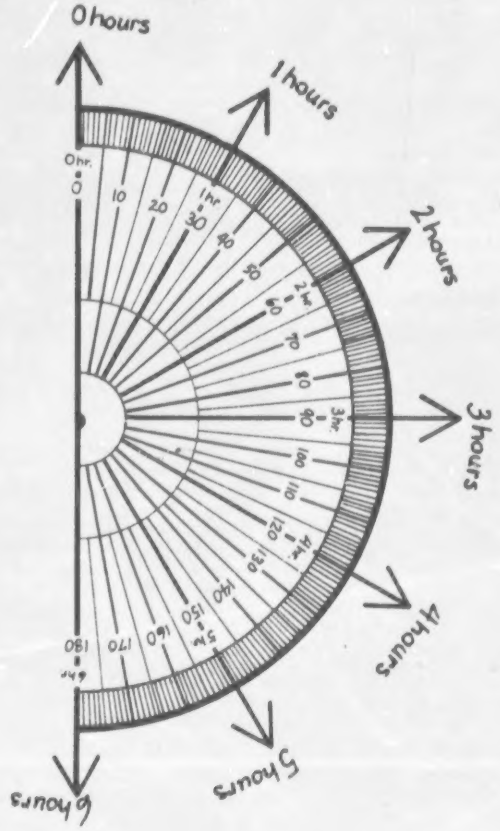

0
1
2
3
4
5
6
7
8
9
10
11
0
360
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

Each one of these parts is called a degree.

On the new protractor, there are 180 degrees.

There are also 6 hours.

Distribute a new transparent protractor to each child and say, "This is the kind of protractor that Studious Jones gave to Super-Sleuth in the story. How is it like the clock protractors on Worksheet 24?"

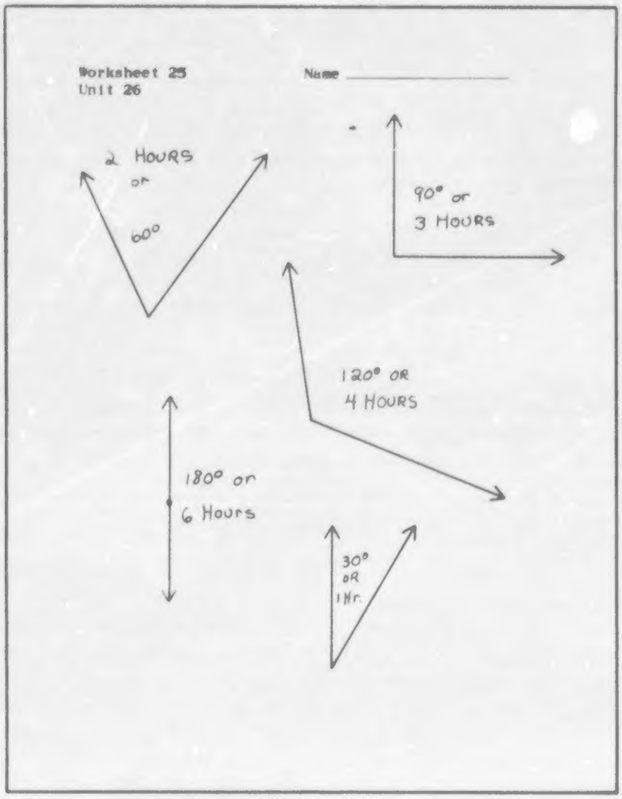

0 hours
1 hours
2 hours
3 hours
4 hours
5 hours
6 hours
0 hr.
0
10
20
1 hr.
30
40
50
2 hr.
60
70
80
3 hr.
90
100
110
120
4 hr.
130
140
150
5 hr.
160
170
180
6 hr.

In the discussion, bring out the following similarities and differences:

1. Both have hour marks.
2. Both are in clock form, though this transparent one is only half a clock.

Differences:

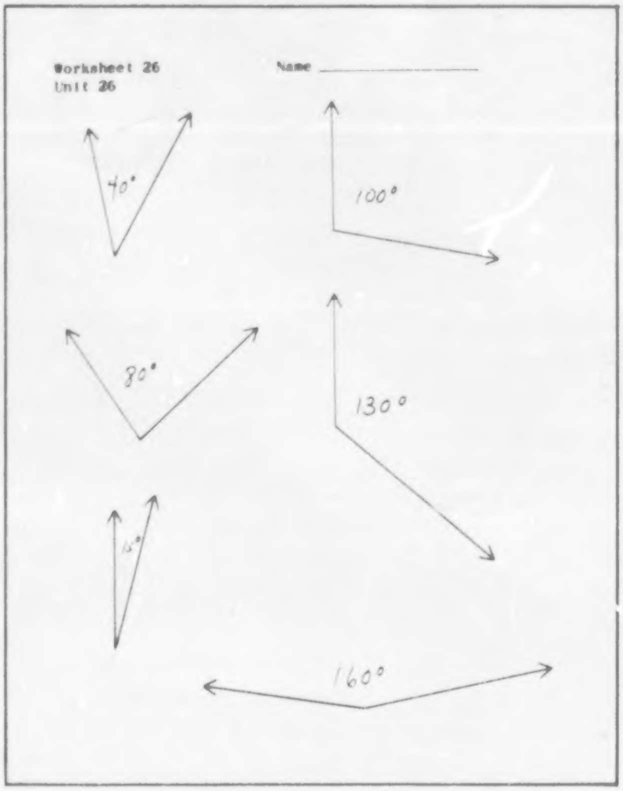
1. The transparency is larger than the full clock protractor.
2. The transparency has more marks (more units) than the full clock protractor.
3. The new clock protractor is numbered from 0 to 180 degrees, and also with hours 0 through 6.



Worksheet 25
Unit 26

Name ______________

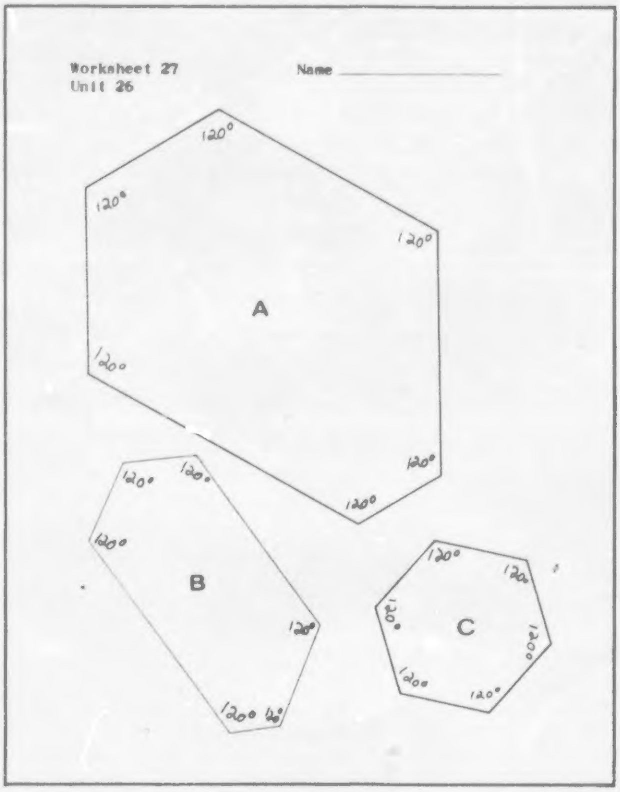
2 HOURS
or
60°
90° or
3 HOURS
120° OR
4 HOURS
180° or
6 Hours
30°
OR
1 Hr.



Worksheet 26
Unit 26

Name ______________

40°
100°
80°
130°
15°
160°



Worksheet 27
Unit 26

Name ______________

120°
120°
120°
A
120°
120°
120°
120°
120°
120°
B
120°
120°
120°
120°
120°
C
120°
120°
120°
120°

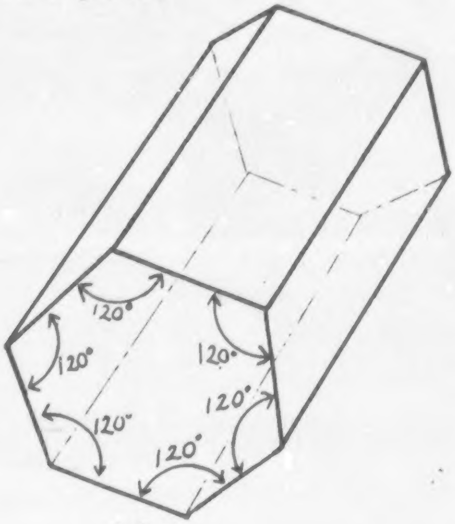
Tell the children:

> WITH THIS PROTRACTOR WE HAVE A CHOICE OF MEASUREMENT UNITS. WE CAN MEASURE THE MAG OF ANGLES EITHER IN DEGREES OR IN HOURS -- JUST AS WE CAN MEASURE LENGTH IN UNITS THAT ARE INCHES, OR FEET, OR YARDS.

Have the children open their Student Manuals to Worksheet 25. Show how to place the dot at the center of their protractors directly over the "corner" of each angle (where the two rays originate). Ask them to line up the zero line with the ray at the left. Have them practice doing this and go about the room checking to see that all the children know where to place their protractors in order to measure the mag of an angle correctly. When the children know how to use the protractors, have them measure the angles on Worksheet 25 in both degrees and hours.

Next have the children measure the angles on Worksheet 26, giving only the number of degrees.

Ask the children to complete Worksheet 27. In discussing the results, the children should see that all the angles measure 120 degrees, even though the figures are very different in side length. Then say that scientists who have looked at many such six-sided crystals have found that all those they examined have parallel surface angles of 120 degrees. This leads them to theorize that all crystals of similar shape have angles of 120 degrees.



Continue by saying that in nature, one seldom finds a perfect quartz crystal like the model the children made. Then go on to say that if a scientist found a broken crystal, or an irregular one, and if it had even one angle with a mag of 120 degrees, he could use this information to hypothesize that it might belong to the hexagonal set of crystals. He could use this hypothesis as a starting point for further study.

Tell the children that they will need their transparent clock protractors in the next lesson. (You may wish to collect the protractors now and distribute them again, as needed.)

You might like to conclude this lesson by asking the children if they think Super-Sleuth could have learned how to use the protractor if he had really tried.

Lesson 16: SHAPES RESULTING FROM CLEAVAGE

Calcite

In this lesson the children find out about the property of cleavage -- the characteristic of some minerals to break in a distinctive way along flat surfaces. First the children peel off thin layers of selenite with their fingernails and see how this mineral cleaves into pieces that have flat surfaces. Next they observe how calcite cleaves (always into pieces with six flat surfaces that are parallelograms with all sides slanted). Then you give a demonstration of a mineral (topaz) that does not have the property of cleavage -- it breaks into pieces in no distinctive way. The pieces are just jagged lumps.

The children learn that the property of cleavage can be used as a guide in trying to determine what a mineral might be. If they can peel a mineral sample into thin layers with their fingernails, it might be selenite. If they can break a mineral into pieces each of which has six faces, all of a characteristic slanted parallelogram shape, it might possibly be calcite. And, if a mineral does not have a definite pattern of cleavage, the children can hypothesize that it is probably neither selenite nor calcite.

In the last activity of the lesson, the children make a model of a box with rectangular faces. They push the top of the box so that the front and back look like calcite faces. But when they look at the other faces, they see that they are not slanted like calcite -- they are rectangles. The children then cut the model until it represents a calcite crystal. They observe the differences and measure the mags of the angles. They discover that each calcite crystal face has opposing equal angles. Two opposing angles have a mag of 78 degrees and two have a mag of 102 degrees. At the end of the lesson the children are able to distinguish the shape of a calcite face from other shapes. They are also able to check by measuring the mag of the angles. This is a follow-up on the work previously done with hexagonal shapes.

MATERIALS

- all samples of selenite and calcite and 1 sample of topaz
- rock or hammer for demonstration of cleavage
- newspaper pad for pounding
- 3 pieces of black construction paper
- Worksheets 28, 29 and 30
- paper and pencils
- grease pencils
- protractors from previous lesson

PROCEDURE

Activity A

Remind the children that in previous lessons they discovered several properties that helped them to identify materials. Briefly review with them some of those properties: hardness, weight, volume, density and shape. Then say that in this activity you want the children to see if they can discover another property that will aid in identifying some minerals.

Have the children gather around a demonstration table on which you have placed eight samples of selenite, eight samples of calcite, one sample of topaz, a tray, three sheets of black construction paper and a rock or hammer. Ask the children to sit on the floor during this activity. Place a sheet of black paper in a tray and put one sample of the selenite on the paper. Ask the children to try breaking off pieces of the selenite with their fingernails as the tray is passed around to them. It may take a little experimentation, but soon the children will discover that they can peel off thin layers of the mineral in this way. When everyone has had an opportunity to see how the selenite separates, take the tray and set it aside for later observation and discussion.

Next pass around the eight samples of calcite. Ask the children to try breaking the calcite samples with their fingernails. (They will not be able to do so.) Then wrap a sample of calcite in a thick padding of newspaper (to avoid flying particles) and pound it with a rock or hammer until it breaks. Try pounding rather gently at first and increase the force only if necessary, as some samples cleave more easily than others. Place the calcite sample and the pieces on another sheet of black paper and put aside for later use.

Similarly wrap a sample of topaz and break this as you did the calcite. Place the pieces on a third sheet of black paper.

Ask the children to examine the minerals on the three sheets of black paper and tell you what they observe. Ask questions that will help in their observations, such as:

> HOW DID THE SELENITE BREAK? WHAT DO THE PIECES LOOK LIKE?

The children should pick up the pieces. They should be able to say that the selenite broke off in pieces that had flat surfaces.

Next, direct attention to the calcite pieces.

> HOW DID THE CALCITE BREAK APART? DID IT BREAK IN ANY PARTICULAR WAY?

Encourage the children to handle the pieces until they are able to state that the calcite also broke off into pieces with flat surfaces. They should also notice that each piece has the shape of a "slanty box". Then say:

> THE SELENITE PEELED OFF IN LAYERS ALONG FLAT SURFACES. THE CALCITE ALSO BROKE ALONG FLAT SURFACES. NOW LET'S LOOK AT THE TOPAZ AND SEE HOW THAT BROKE.

The children should touch and look at the broken pieces of topaz. They should be able to see that there is a difference in the way the topaz broke and in the way the other two minerals broke. They should see that the pieces of topaz had no definite flat surfaces nor particular shape.

When the children have discussed their observations as fully as they can, give them this definition of the new property of minerals that they have just seen demonstrated:

> WHEN CRYSTALLINE MINERALS CAN BE BROKEN APART IN DEFINITE WAYS ALONG FLAT SURFACES, WE SAY THAT THEY CLEAVE, OR THAT THEY HAVE THE PROPERTY OF CLEAVAGE. WHICH OF THE THREE MINERALS THAT WE BROKE APART HAVE THAT PROPERTY? (The selenite and the calcite.) WHICH DOES NOT HAVE THE PROPERTY OF CLEAVAGE? (The topaz.)

Now discuss with the children whether or not this new property could be of any value in identifying a material. Ask:

> IF YOU HAD A MINERAL THAT YOU COULD PEEL OFF IN SMOOTH FLAT PIECES WITH YOUR FINGERNAIL, WHAT HYPOTHESIS MIGHT YOU MAKE ABOUT IT? (We could use it as one hint that the mineral might be selenite.)
>
> WHAT OTHER TESTS HAVE YOU LEARNED DURING THE STUDY OF THIS UNIT THAT YOU COULD THEN TRY ON THE UNKNOWN MINERAL? (We could observe it, test it for hardness, density and shape.)
>
> IF YOU HAD A MINERAL THAT YOU COULD BREAK INTO PIECES THAT LOOKED LIKE LITTLE SLANTED BOXES, WHAT HYPOTHESIS MIGHT YOU MAKE ABOUT THAT? (That it might possibly be calcite.)
>
> WHAT OTHER PROPERTIES MIGHT YOU THEN INVESTIGATE? (Its appearance, its hardness, density and shape.)

Now ask the children what hypothesis they might make if a mineral broke in the way that the topaz broke -- that is, in rough lumps of no particular shape. The children should be able to tell you that they might hypothesize that the topaz probably was not either selenite or calcite and belonged to a set of minerals with the property of "no cleavage."

Put away the selenite and topaz samples, and keep all eight calcite samples for use in the next activity. Tell the children that soon they are going to try to find out more about the cleavage of calcite.

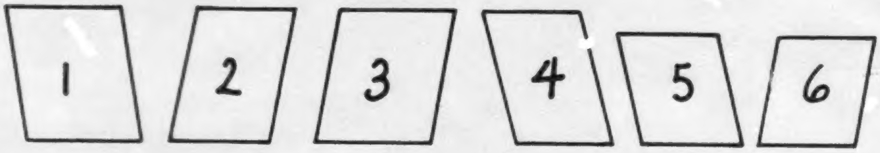
Activity B

Divide the class into seven groups and provide each group with one sample of calcite. Ask the children if they recall what the small numeral "3" on one face of the calcite indicates. (Its hardness in Mohs' Scale.) Tell the children you want them to ignore this numeral and number each face of the calcite (1 through 6) with a grease pencil until each face has a number. Demonstrate to the children how they can start on any face of the calcite and keep turning it until they have numbered all the faces. Select one member from each group to do this. If you have only three grease pencils, ask the groups to pass them along and share them. When the numbering has been completed, check each sample to see if the numerals are legible. Collect the grease pencils.

Now ask each group to use just one sheet of paper for tracing around all six faces of the calcite with a pencil. Demonstrate how they are to do this. To trace face # 1, they should put that face down on the paper. When they have finished drawing the outline of the face, they should number the drawing with the appropriate numeral. To avoid confusion, and to give each child a part in the activity, assign the tasks. If there are five children in a group, for example, you might write these tasks on the board:

Child 1 traces around face # 1 and writes "1" inside his tracing.
Child 2 traces around face # 2 and labels his tracing "2."
Child 3 traces and labels face # 3.
Child 4 traces and labels face # 4.
Child 5 traces and labels face # 5.
Child 1 traces and labels face # 6.

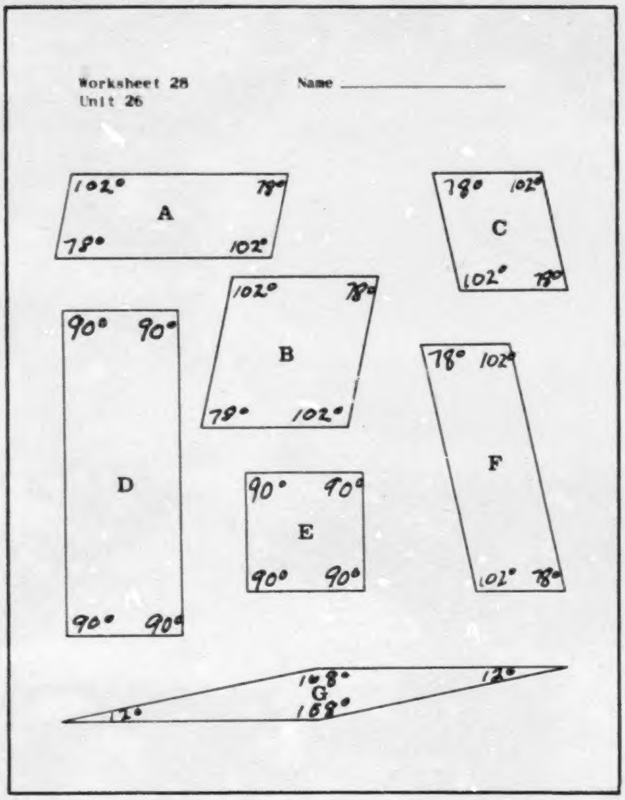
When they have finished doing this, each group should have one sheet of paper with six labeled outlines on it, like this:



Now ask the children:

ARE THESE SHAPES ALIKE? HOW ARE THEY ALIKE?

The children should see that the shapes they have drawn are like slanted boxes. Next ask them to turn to Worksheet 28. Ask if they can figure out which outlines were traced from a calcite mineral sample.


Worksheet 28
Unit 26

Name ____________

Accept all suggestions. If the children are having difficulties, direct their attention to the angles of each figure. Ask:

ARE THERE CERTAIN MAGS THAT CAN BE ASSOCIATED WITH THE ANGLES OF THE CALCITE FACES?

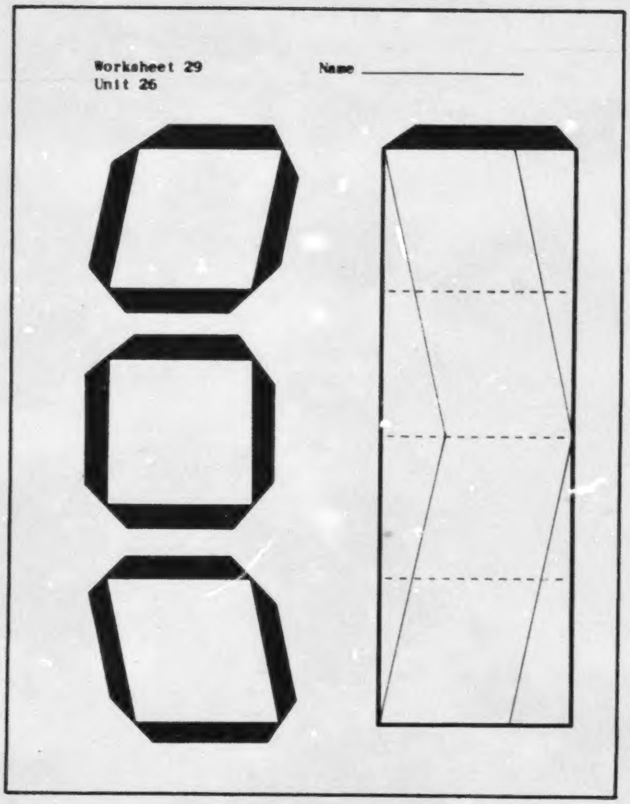
Remind the children that angles were found useful when they were looking at hexagonal crystals. All those angles had a mag of 120 degrees. Perhaps if the mags of the calcite angles were measured, the children could find out something useful about those, too.

Provide the children with the transparent protractors from the previous lesson and ask them to try measuring the angles on their calcite samples. Allow for some error. They should get measurements of approximately 100 degrees and 80 degrees (actually 102 and 78). Now have them measure the angles of the tracings they drew of the calcite faces. (They should get results very similar to those of the calcite itself.) As a third measuring exercise, ask the children to turn to

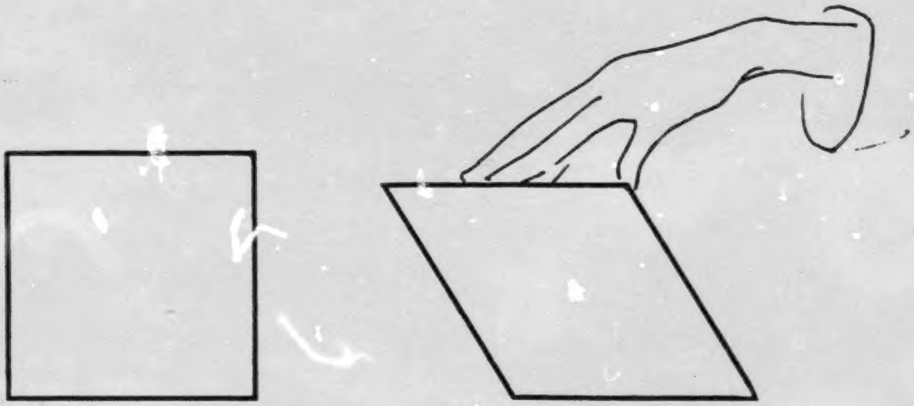
Worksheet 28 again and measure the angles in the figures shown there. When the children have finished measuring and marking in the mag of each angle, ask if they can tell more easily now which shapes were traced from calcite and which were not. If some are still unsure at this point, do not be unduly concerned. In the next activity the children will build calcite models and obtain a better understanding of the shape of the calcite crystal.

Activity C

Ask the children to remove Worksheet 29 carefully from their Student Manuals. Provide scissors and ask them to cut off the right half of the worksheet (the part that has one long figure printed on it) and to put the left half away for the time being.



Now have the children cut along the heavy black border lines of the long rectangle and around the black flap at the top of it. (They should ignore the slanted lighter lines.) After each model is cut out, the children should fold along the three dotted horizontal lines, and fold in the black flap. Provide cellophane tape and have them tape the flap in place. When they have done this, the children should each have a model that looks like a box with its front and back ends missing. Check to see that everyone has such a model. Now ask the children to look at either open end of their models and describe the shape they see. (Each open end is square.) Next ask the children to look at the other faces of their models and describe the shape of those. (These four faces are all rectangles.) Tell the children to place the models on their desks and, with their fingers, press the box shape until its sides are slanted toward the left.



With your fingers, press one side of the model so that the angles of the open end change. Holding it in this position, ask the class to describe what they see.

> DOES THIS OPEN END LOOK LIKE A SQUARE NOW? (No.) WHY DOESN'T IT? (The sides slant. The angles are not the same.)
>
> WHAT DOES THIS SLANTED SHAPE LOOK LIKE? (It looks like one face of a calcite crystal.)

Still holding the model so that its open ends slant, ask the children to describe the four closed sides. (They are still rectangles.) Then ask:

> IF THIS MODEL HAS FOUR RECTANGULAR FACES AND ONLY TWO ENDS THAT SLANT, IS IT A GOOD MODEL OF A CALCITE CRYSTAL? WHY OR WHY NOT?

In the ensuing discussion the children should agree that what you have been holding up is not a model of a calcite crystal at all. If it were, all six faces would have slanted sides.

Let them check this with calcite samples, and with their own models with the two open ends pressed aslant.

Suggest that the children take their scissors and cut through the tape that holds their cardboard models together. This time they should cut along the slanted lines of the figure, fold along the same lines as before, and tape in the flap. Ask:

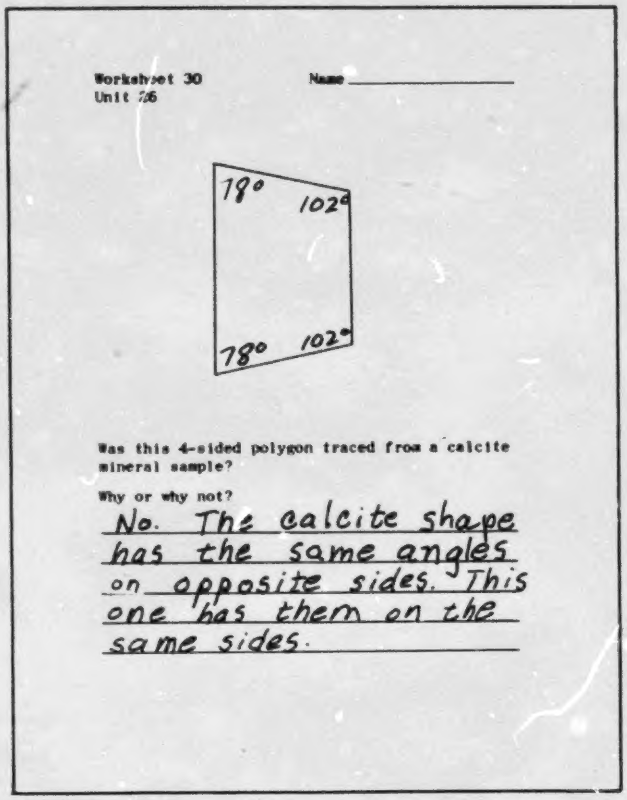
> WHAT DOES YOUR NEW MODEL REPRESENT? (A calcite crystal with two faces missing.)

Ask the children to check and see if all the faces have slanted edges. (They all do.)

Have the children get the other half of Worksheet 29 and cut out the three shapes printed on that. Tell them that, when they have bent back the black flaps on each model, they are to choose from the three shapes those that are most appropriate to complete the missing faces on their calcite models. When they choose to tape in the two shapes that have all sides slanted, ask why. The children will say that they are choosing the shapes with the slanted sides because all sides of a calcite crystal slant. Ask:

> WHAT DO YOU MEAN WHEN YOU SAY THE SIDES ARE SLANTED? (The angles are different from those of a square or rectangle.)

Distribute protractors and have the children measure the mag of each angle on their calcite models. The angles should measure either 78 degrees or 102 degrees, but allow for a little error. Accept measurements that are within three or four degrees of the ideal. Have the children write the mag of each angle directly on the model. Then ask them to measure the angles on the square face they did not use, and to mark in the mags on that. A discussion after these measurements should lead the children to see the differences between a square (or other rectangle) and a calcite face. The square (or any other rectangle) has four straight sides and four angles, each with a mag of 90 degrees. All sides of a calcite face are slanted and the angles are 78 degrees and 102 degrees (approximately 80 and 100).



Worksheet 30 Name ________________
Unit 26

78°
102°
78°
102°

Was this 4-sided polygon traced from a calcite mineral sample?

Why or why not?

No. The calcite shape has the same angles on opposite sides. This one has them on the same sides.

Have the children turn to Worksheet 30. Ask the children if the figure printed on that worksheet could be a calcite face. Have them vote yes or no. Then ask those who said yes, why they did so. Ask those who voted no why they did so, too. Then ask the children to measure the angles of the figure on Worksheet 30. They will discover that the angles on this figure have mags of 78 and 102 degrees. When they have done this, ask the children to count the sides of the figure. (It has four sides.) Then say:

> THE FIGURE ON WORKSHEET 30 HAS ANGLES OF THE SAME MAG AS THE CALCITE FACE. IT ALSO HAS FOUR SIDES, JUST AS CALCITE DOES. WHY, THEN, CAN'T WE SAY THAT IT IS THE SAME AS A CALCITE FACE?

The figure on Worksheet 30 is so different in appearance from that of a calcite crystal face that the children may think it is strange to even consider this question. But they may have difficulty in describing what is really different about the two shapes. What you want to elicit here is that a calcite face has two opposing angles of 78 degrees and two opposing angles of 102 degrees. Also a calcite face has opposite sides that slant in a parallel manner. This means, that no matter how far they were extended, the two lines (sides) would never meet.

As a conclusion to this section on crystal shapes, you might wish to tell the class the shape of one calcite face is called a rhombus, and to ask them to name other crystal face shapes they have studied. (Hexagonal in the quartz studies, and square in the study of salt faces.)

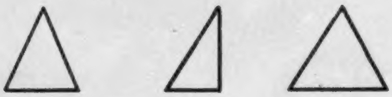
Optional Discovery Activity

The purpose of this enrichment activity is to have the children discover some interesting relationships between the total mag measurements of polygons with different numbers of sides. It also gives them an opportunity to draw a number of different polygons and to use their new protractors again.

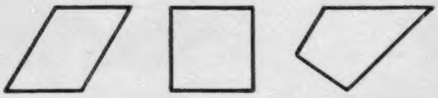
. . . .

The following information is provided as teacher background:

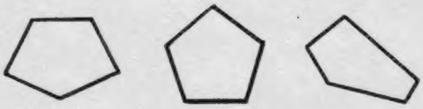
For all 3-sided polygons, the total mag of the angles will equal 180 degrees.



For all 4-sided polygons, the total mag of the angles will equal 360 degrees.



For all 5-sided polygons, the total mag of the angles will equal 540 degrees.



For all 6-sided polygons, the total mag of the angles will equal 720 degrees.

Notice that each time another side is added to a polygon, the total mag of the angles is increased by 180 degrees.

. . . .

Some children in your class may have noticed that the angles of the calcite face (4-sided polygon) had a total mag measurement of 360 degrees. Challenge them to find out if this is true of any other 4-sided polygons. Have them use their rulers when drawing the 4-sided polygons so that the angles will be sharply defined and easy to measure with their protractors. If the children measure the angles of each 4-sided polygon and record the total mag for each, they should discover that all the measurements total about the same. (Each 4-sided polygon has a total mag measurement of approximately 360 degrees.)

Some children may remember that the hexagonal shape that was associated with the quartz and corundum crystals had six equal angles, each of which measured 120 degrees. If they totaled six 120-degree angles they would get 720 degrees. Challenge them again to find out if this would hold true of other 6-sided polygons.

Some children may want to carry out the same procedure for 3-sided and for 5-sided polygons. When they have done this, ask them to list in order, the approximate total mag measurement for each polygon, starting with the 3-sided. Such a list might look like this:

Polygons	Total mag of angles
3-sided	180 degrees
4-sided	360 degrees
5-sided	540 degrees
6-sided	720 degrees

Ask them if they can find an interesting pattern in their data. This will give the children an opportunity to discover that each time [illegible] side is added to a polygon, its total angle measurement increases by 180 degrees.

Theoretically the above would be true in all instances, but limit the children's statement of results to what they have actually discovered for themselves. (See the discussion on the next page.)

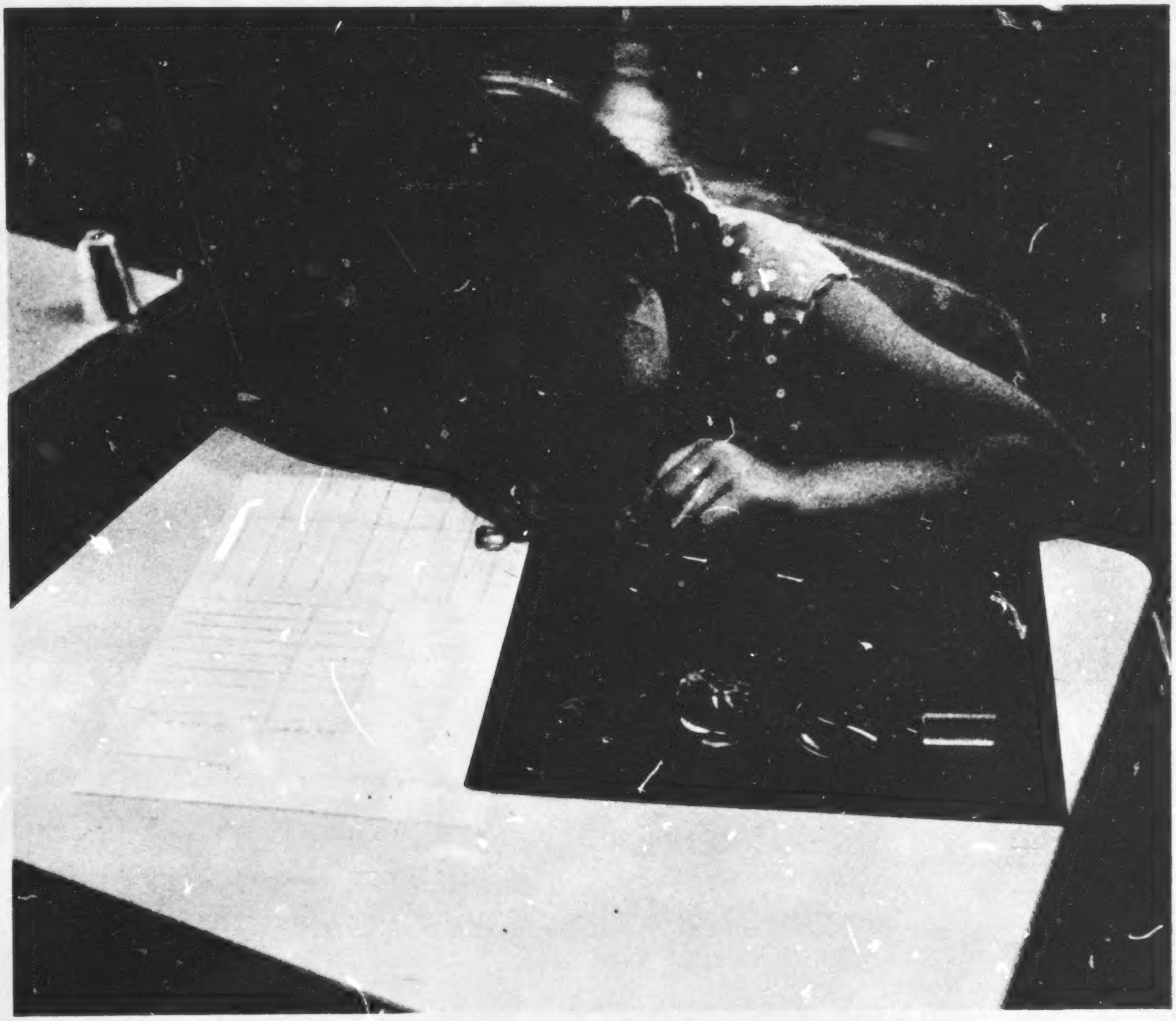
> ALL THE THREE-SIDED POLYGONS THAT I MEASURED SEEMED TO HAVE A VERY SIMILAR TOTAL ANGLE MEASUREMENT. (That is, 180 degrees.)
>
> ALL THE FOUR-SIDED POLYGONS THAT I MEASURED SEEMED TO HAVE A VERY SIMILAR TOTAL ANGLE MEASUREMENT. (That is, 360 degrees.)

Some children may wish to go on to measure the angles of 7-sided and even 8-sided polygons. They should be encouraged to do so.

Almost all children enjoy using the protractors. You might like to let them take their protractors home overnight or for the weekend, either to show their families what they have learned or to report on interesting polygon shapes they found to measure. Be sure the protractors are returned for use in later units.

SECTION 7

SOLUBILITY



SECTION 7 THE PROPERTY OF SOLUBILITY

PURPOSE

- To have the children discover, by experimentation, another property that can help identify a material -- the property of solubility.
- To have the children experiment with two very different kinds of solvents (water and vinegar) not only to observe various properties of solvents but also to let them hypothesize that there may be other solvents, too.
- To introduce the notion of chemical reaction as a natural preparation for the work in Section 8.

COMMENTARY

This section consists of only two lessons. Read both of the lessons before starting to teach the section in order to be better prepared. In Activity A of Lesson 17 the children observe the dissolution of a small sugar cube in a little water. They observe this process through magnifiers and notice that, as air is gradually replaced by water in the cube, most of the sugar dissolves in the water and is no longer visible. They then discover that, by stirring, they can make all of the sugar disappear into the water.

In Activities B and C of Lesson 17, the children measure the quantities of the substances they use to make solutions. In Activity B they start with a given amount of water and see how many scoops of a substance it will completely dissolve. In Activity C the children start with a given amount of the substance and see how many drops of water it takes to dissolve it completely. If you wish, these saturated solutions can be used for a crystal-growing experiment. At the end of this lesson the children are asked to think of any other liquids that might dissolve substances.

In Lesson 18, vinegar is the solvent. The children use it to try to dissolve five substances: sugar, salt, soda, starch and detergent. They discover that vinegar will not completely dissolve all of these substances. They also discover that when vinegar is added to soda, bubbles appear. This chemical reaction is used to have the children see that this may be another property that would aid in the identification of materials. At the end of the section they are asked to consider whether or not there are other kinds of chemical reactions they might use to help in identifying materials.

Teaching time for this section should be about two class periods.

PREPARATION

Materials and their preparation are usually given with the lessons but the following materials will be used throughout the rest of the unit and are listed here for your convenience. You will find it helpful to prepare these things now. Making the scoops is easy if you follow the instructions given. One scoop is used for each of the containers to avoid contamination of substances.

Get 32 four-ounce plastic containers from the kit. Fill each container to the 1-ounce mark with white substances as listed below. Be sure to label each container with the name of the substance on masking tape. This is what you will need for a class of 32:

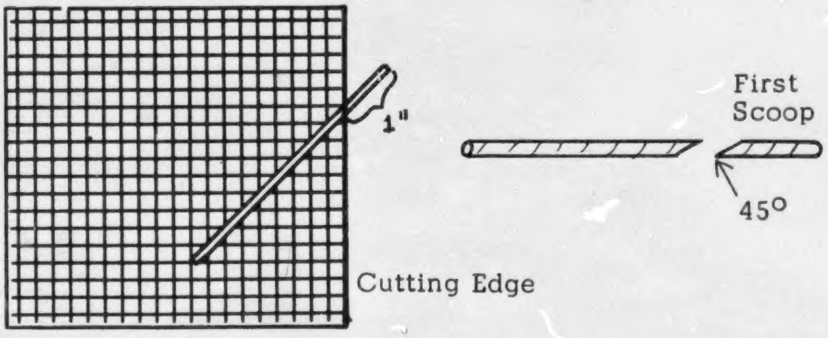
8	(4 oz.) containers, each with 1 oz.	granulated sugar
8	" " " " "	table salt
4	" " " " "	baking soda
4	" " " " "	cornstarch
2	" " " " "	detergent
2	" " " " "	plaster of Paris
2	" " " " "	chalk powder
2	" " " " "	Epsom salt

All of the above substances except sugar and table salt are provided in the OMSI kit.

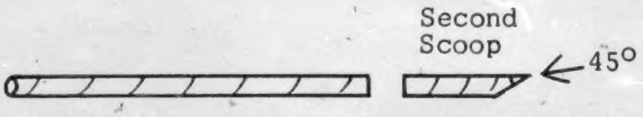
The kit also contains 7 plastic straws and 32 yellow Tinkertoy parts for making the scoops. In addition to these, you will need a paper cutter and tape.

How to make the scoops:

Step 1 Place a straw on the paper cutter so it goes through the diagonals on the grid and one end of it extends about an inch past the cutting edge. Cut. The result will be a 45-degree angle on your first scoop.



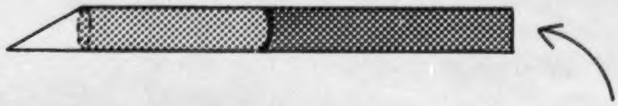
Step 2 Place the straw horizontally on the paper cutter and cut off the point about one inch from the end for your second scoop.



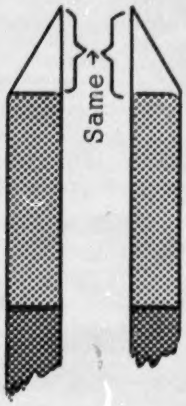
Repeat the procedure until you have 32 scoops.

Step 3 Push the blunt end of a scoop over the end of a yellow Tinkertoy until the Tinkertoy reaches the short end of the angle.

Scoop Made from Straw



Step 4 When all the scoops and handles are joined, check the distance from the tip of the scoop to the handle, using one scoop as a standard. Make adjustments if necessary.



To prevent loss of the scoops, you may want to place them in the containers of white substances immediately.

Lesson 17: DISSOLVING SUGAR AND SALT IN WATER

The purposes of this lesson are to introduce the property of solubility to the children and to let them discover, through experimentation, how two different substances vary in this property.

Activity A is an individual experiment. Each child has his own small sugar cube and container of water in which to dissolve it. Each child observes the process of dissolution through his hand magnifier.

In Activity B each group of four children starts with a given amount of water and experiments to find out if this amount of water will dissolve more sugar, more salt, or the same amount of each. The children measure the substances and keep a tally of how many scoops of each material can be completely dissolved in 2 cm of water. When a solution becomes saturated with a substance, additional particles will not dissolve and no more of the substance should be added. The children will discover that more sugar will go into solution than salt -- that is, sugar is more soluble than salt. This is a good activity to do just before lunch to find out whether the solutions will dissolve more of the substances after lunch. Saturated solutions of sugar and salt may be used for crystal-growing.

In Activity C, each child starts with a given amount of each substance (1 scoop) and finds out how many drops of water it takes to dissolve it. The children discover that it takes less water to dissolve the sugar than it does the salt, reaffirming their findings in Activity B -- that sugar is more soluble than salt. The children record their findings on Worksheet 31.

It is important that all containers be washed thoroughly after each experiment. Soaking the empty containers in hot water for a while should simplify this task. One or two children could be given this responsibility.

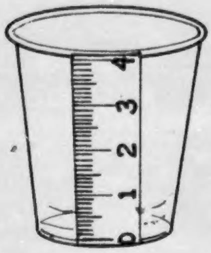
MATERIALS

-- Activity A (for each child) --

- 1 sugar cube (small "cocktail" size)
- 1 one-ounce plastic container with half-ounce of water
- 1 toothpick
- 1 magnifier
- 1 small (4" x 4") square of black construction paper

-- Activity B (for class use) --

- 1 one-ounce container with 0 - 4 cm tape on the side, for measuring water



-- Activity B (for each group of 4) --

- 1 tray
- 4 one-ounce containers, each with water to 2 cm mark
- 4 new toothpicks
- 4 small squares (4" x 4") of black construction paper
- 1 four-ounce container of salt, with scoop
- 1 four-ounce container of granulated sugar, with scoop

-- Activity B (optional) --

- 4 four-inch cylinders from volume-measuring lessons
- saturated salt solution (enough to fill 2 cylinders)
- saturated sugar solution (enough to fill 2 cylinders)

-- Activity C (See PREPARATION.) --

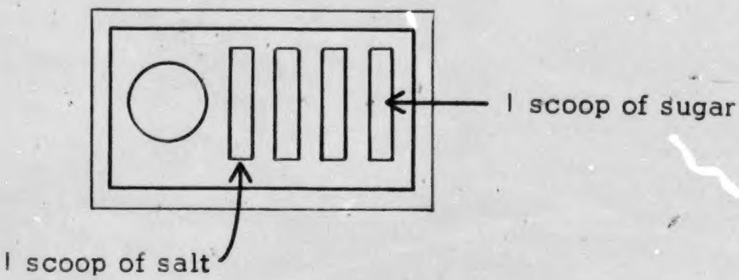
- 1 container of salt, with scoop
- 1 container of sugar, with scoop

-- Activity C (for each child) --

- 1 reaction tray, with scoop of sugar and salt
- 1 medicine dropper
- 2 new toothpicks
- 1 four-ounce container with 2 ounces of water
- Worksheet 31

PREPARATION

Assemble the materials for the different activities on trays. You may want the children to help you with this. The reaction trays for Activity C should look like this:



PROCEDURE

Activity A

Assign five children to distribute each of the five materials. When all the children have their materials, ask them to place the square of black paper under the water container. Then say that you want them to observe, with their magnifiers, what happens to a sugar cube when it is placed in water. Have them drop their cubes into the water.

As the cube dissolves, discuss with the children what they see happening. Some possible observations and discussion points are:

1. Bubbles float to the surface of the water. Ask the children to hypothesize why this is happening. (Air is escaping.)
2. The cube begins to crumble -- little pieces break off and fall to the bottom of the container.
3. About three-fourths of the cube breaks down.

Now have the children use their toothpicks to break up the rest of the cube. Discuss what happens. (The sugar disappears.)

Ask:

> WHERE DID THE SUGAR GO? DID WE REMOVE ANYTHING FROM OUR CONTAINERS? (No.)
>
> IS THE SUGAR STILL IN OUR CONTAINERS? HOW CAN WE FIND OUT?

Tasting is the best suggestion here. Let the children do this, but remind them that tasting should never be used to test an unknown substance. Say that, in this case, you are sure that nothing has been put into the containers but sugar and water, and therefore you are permitting the children to use the tasting test.

Ask the children how the water tasted and what they can surmise from this. (The water tasted sweet; therefore, the sugar is still there, but it can't be seen.)

Ask the children if they know a word that describes what happens when sugar disappears like this in water. If no one thinks of "dissolve," give them this word. Reiterate:

> WHEN A SUBSTANCE MIXES WITH A SOLUTION SO THAT THE SUBSTANCE DISAPPEARS -- SO THAT NO PARTICLES OF IT CAN BE SEEN -- WE SAY THAT THE SUBSTANCE DISSOLVED.

Then ask:

WILL SOME MATERIALS DISSOLVE MORE EASILY THAN OTHERS?

Let the children speculate. Have them name some obvious examples of materials that do not dissolve as easily as sugar, such as sand, wood, plastic, steel, copper, glass, minerals, people, vegetables, etc.

WHAT ABOUT SUGAR AND SALT? DO YOU THINK ONE OF THESE SUBSTANCES WILL DISSOLVE AS EASILY AS THE OTHER? HOW CAN WE FIND OUT?

Ask the children to make suggestions for experimental procedure and apparatus. They will probably suggest measuring quantities of materials and water used. If they don't, ask them to remember some of the scientific procedures they learned in Unit 23, Conditions Affecting Life.

At the conclusion of this discussion, ask one or two children to collect the equipment. The black squares can be saved for the next activity. The toothpicks and sugar solution should be thrown out. The containers should be thoroughly washed and rinsed in warm water. Eight clean containers should be kept handy for use in Activity B.

Activity B

A half-hour before lunch is a good time to start this activity.

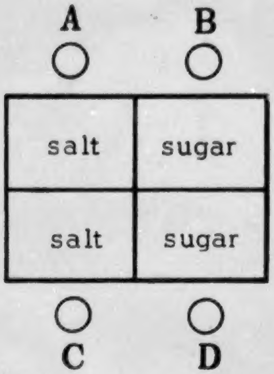
Hold up two 1-ounce containers, each containing 2 cm of water, and pose this problem to the class:

IF WE HAVE TWO CONTAINERS, LIKE THESE, WITH THE SAME AMOUNT OF WATER IN EACH -- AND IF WE PUT SUGAR IN ONE AND SALT IN THE OTHER -- WOULD WE BE ABLE TO DISSOLVE THE SAME AMOUNTS OF SUGAR AND SALT?

WOULD WE BE ABLE TO DISSOLVE MORE OF ONE SUBSTANCE THAN OF THE OTHER? HOW CAN WE FIND OUT? (We should try it.)

HOW WILL WE KNOW WHEN WE CANNOT DISSOLVE ANY MORE SALT OR SUGAR IN THE WATER? (When all the particles will not disappear.)

Divide the class into groups of four and assign each child a letter (A, B, C, D). Have the groups help arrange the desks so that Child A and Child C are facing each other, and beside them, Child B and Child D are facing each other:



Children A and C share the salt container and scoop.

Children B and D share the sugar container and scoop.

Distribute the materials and tell the children that, in each group, A and C will work only with the salt and B and D will work only with the sugar. Each pair of children who are working together will need paper and pencil to keep a tally (~~////~~ /// , etc.) of how many scoops they are able to dissolve. The black squares should be used as in Activity A.

Discuss the following procedure with the class:

1. Put one scoop of material in the water.

2. Hold the container securely and stir with toothpick.

3. When or if all the particles disappear, add another scoop.

4. With paper and pencil, keep a tally of how many scoops are put in.

5. Observe and help your partner if your solution becomes saturated (will dissolve no more particles) sooner than his does.

NOTE: Watch the salt experiments carefully. One scoop of salt makes the water reach the saturation point. If the children can see small particles, they should not add any more.

Ask the children to do the experiments. If they started before lunch, have them leave their equipment in place until after lunch. At that time, the children should check their solutions. If all particles are now dissolved, they should add another scoop and try to dissolve that. Some children may be able to dissolve another scoop or two of salt. The children who have sugar may be able to dissolve as many as 35 scoops.

When the children conclude that their solutions have reached the saturation point, make a class tally chart (similar to the following one) of the number of scoops the children were able to dissolve of each substance. List the number of scoops (1-40) and tally the number of children who dissolved each number of scoops.

Chart showing the number of children and the number of scoops of salt or sugar they dissolved in 2 cm of water. Each tally mark represents a child.

Number of Scoops	Number of Children	
	SALT	SUGAR
1	𝍸 𝍸 𝍸	
2	𝍷𝍷	
3	𝍷	
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
▒	▒	▒
30		𝍸 𝍷
31		𝍷𝍷
32		𝍷𝍷𝍷
33		𝍷𝍷𝍷
34		𝍷
35		𝍷𝍷𝍷
36		
37		
38		
39		
40		

From this data, the children should be able to conclude that more sugar than salt can be dissolved in a given amount of water. Therefore, sugar is more soluble than salt -- more sugar goes into solution than salt.

NOTE: If you wish to make crystals, have the cleanup crew pour the saturated sugar solutions into two four-inch cylinders. Mark these "Sugar Solution." Also have them pour saturated salt solutions into two cylinders and label these. Tell the children you are going to let these solutions stand for a while. Ask what they think will happen as the water evaporates. Have the children check the cylinders every day. Within a few weeks (probably after the conclusion of this unit) sugar and salt crystals will form on the sides of the cylinders. The children can observe these closely with their magnifiers. Crystals will form more quickly in a warm place, but put the cylinders anywhere where the children are not apt to knock them over. However, even if there is some spillage, enough material will cling to the sides of the cylinders to form crystals.

Have the cleanup crew thoroughly wash and rinse the containers used in the experiments. They should throw away the used toothpicks. The black squares can be stored for use next year.

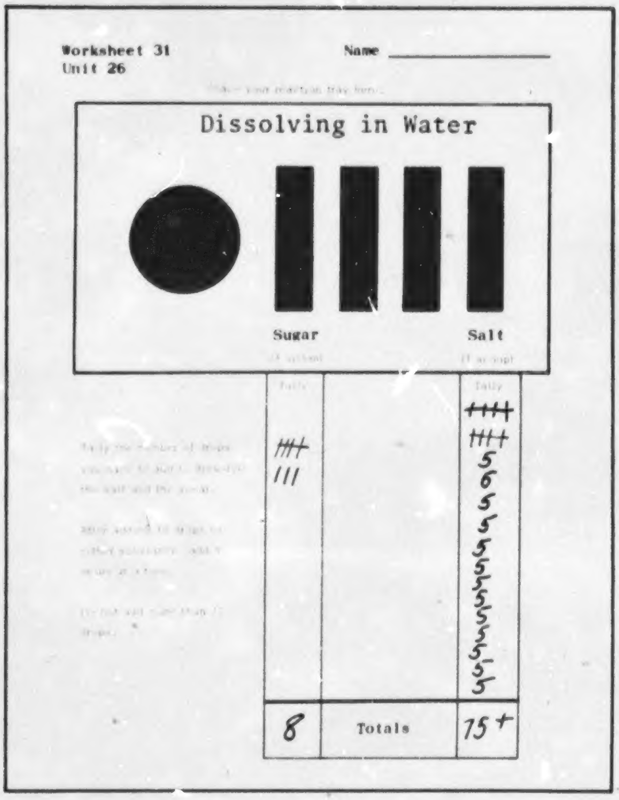
Activity C

Raise this question:

IF YOU HAD ONE SCOOP OF SALT AND ONE SCOOP OF SUGAR, WHICH MATERIAL WOULD TAKE MORE WATER TO DISSOLVE?

Let the children speculate. From their work in the previous activity some children may be able to hypothesize that since sugar is more soluble than salt, it will take less water to dissolve it. This may be too sophisticated a generalization for most of the children to suggest. (This activity should help show the connection.)

See that each child has a tray of materials. Ask the children to remove Worksheet 31 from their Student Manuals. Ask them



Worksheet 31
Unit 26

Name ____________________

Dissolving in Water

Sugar Tally		Salt Tally
~~||||~~ |||		~~||||~~ ~~||||~~ 5 6 5 5 5 5 5 5 5 5 5 5 5
8	Totals	75+

to place their reaction trays on the worksheets in such a way that each well in the tray has a black area under it. Have them each put one toothpick in the salt and the other in the sugar. Be sure they understand they are not to interchange the toothpicks. They are to use the salt toothpick only in the salt, and the sugar toothpick only in the sugar. Explain that this is to prevent contamination. Also, so that the substances do not blow away, ask the children not to breathe too closely over them.

Now have the children use their medicine droppers to put one drop of water into the salt and one drop into the sugar. Say that next they should stir each substance for a few seconds with the appropriate toothpick, but they should stir carefully or they will poke holes in the tray.

If a substance has not dissolved in the first drop of water, each child should add more drops -- one at a time. After the tenth drop they may add five drops at a time. They should keep track of how many drops are added to each substance, and not go beyond 75, even if a substance is not dissolved.

No substance can be considered dissolved until all particles have disappeared. The children may wish to use magnifiers to check for remaining particles.

When all the children have either dissolved the sugar and salt, or used their quota of 75 drops, make a classroom chart of their data:

Chart showing the number of children and the number of drops of water they used to dissolve 1 scoop of salt or sugar. Each tally mark represents a child.

Number of Drops	Number of Children SALT	 SUGAR
1		
2		
3		
4		
5		
6		
7		𝍸 𝍸
8		𝍸 III
9		
10		
░	░	░
75	𝍸 𝍸 𝍸 III	

(still a few particles left)

Discuss the data on the chart with the children. They should be able to conclude (1) that salt does not dissolve as easily as sugar and (2) that sugar is more soluble -- dissolves more easily -- than salt.

Next discuss the usefulness of the property of solubility. Ask the children if solubility could be used as a test to distinguish one material from another, in the manner in which they used results of tests for other properties -- such as hardness, density, etc. They should be able to see that, by the method they have used in this activity, they could test the solubility of a substance and compare it with the solubility of sugar and of salt.

Tell the children that today water was used to dissolve the substances. Suggest that maybe other liquids could be used to dissolve a substance. Ask:

> WILL SUGAR DISSOLVE IN OTHER LIQUIDS AS EASILY AS IT DID IN WATER? WILL IT DISSOLVE DIFFERENTLY IN SOME WAY? WILL OTHER SUBSTANCES DISSOLVE IN THE SAME WAY, REGARDLESS OF WHAT LIQUID IS USED?

Then say that in the next lesson they will find answers to some of these questions.

Assign a cleanup team to throw away the solutions and the toothpicks and to wash and rinse the reaction trays for use in the next lesson.

Save all the worksheets, as the data will be needed in Lesson 20.

Lesson 18: USING VINEGAR AS A SOLVENT

Here the children use vinegar as a solvent, instead of water. They dissolve five dry substances: granulated sugar, table salt, baking soda, cornstarch and powdered detergent. The purpose of the lesson is to let the children discover that water is not the only, and not necessarily the best, solvent. By experimenting, they find answers to questions such as: Will sugar be more soluble than salt in vinegar? Will sugar and salt dissolve differently in vinegar than in water -- that is, will it take more or less vinegar than water to dissolve each substance? Will vinegar dissolve substances other than sugar and salt?

When the children add vinegar to baking soda, they will observe that the mixture bubbles. The lesson ends with a discussion of this phenomenon. The children are told that it is called a chemical reaction and that they will be experimenting with the property of chemical reaction in the next section of the unit.

MATERIALS

- 5 four-ounce containers (with scoops) of the following substances: salt, sugar, soda, detergent and starch

-- for each child --

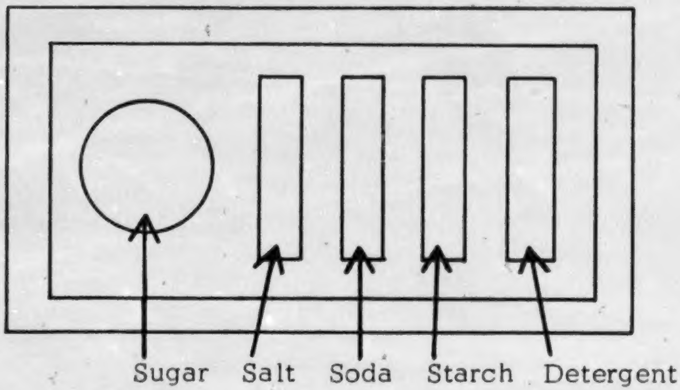
- reaction tray containing one scoop of each of the 5 substances (See PREPARATION.)
- 5 toothpicks, 1 for each substance
- Worksheet 32, pencil
- magnifying glass
- medicine dropper

-- for each pair --

- 1 four-ounce container with 1 ounce of vinegar in it

PREPARATION

Before class, ask five children to help you prepare the reaction trays. Assign one child to put one scoop of sugar in the round well of each tray. Assign a second child to put one scoop of salt in the well next to the sugar. Assign the three other children to put in a scoop of soda, starch and detergent, as shown in this drawing:



Pour one ounce of vinegar into each of 15 four-ounce containers, and provide two medicine droppers per container.

PROCEDURE

Briefly review the findings of the previous lesson -- that some substances dissolve more easily than others. If a substance can be dissolved, it has the property of solubility. Some substances are more soluble than others. For example, the children found out that, in water, sugar is more soluble than salt.

Tell the children that today they will try to find out whether or not it makes any difference what liquid is used to dissolve a substance. Pose these questions:

> IF WE USE VINEGAR INSTEAD OF WATER, DO YOU THINK SUGAR WOULD DISSOLVE IN IT MORE EASILY THAN SALT?

WOULD SALT BE MORE SOLUBLE IN VINEGAR THAN SUGAR?

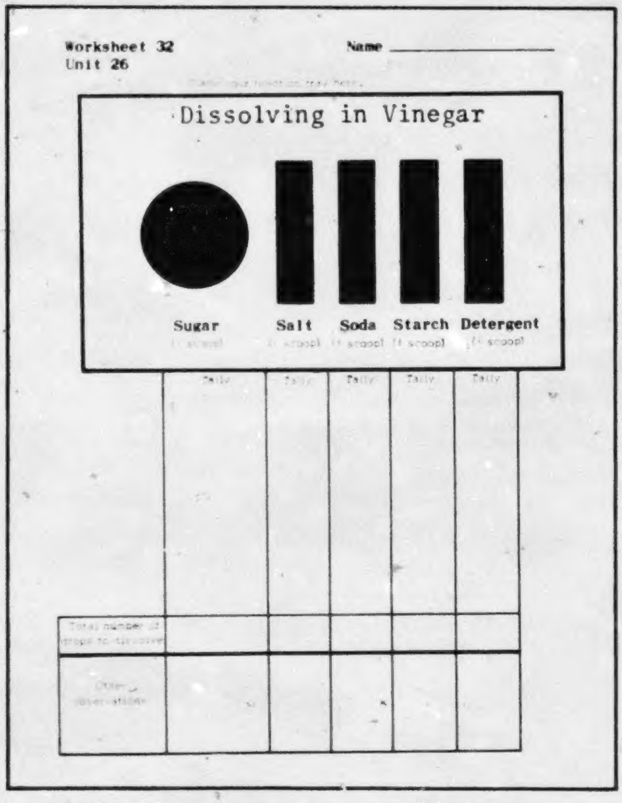
WILL BOTH BE ABOUT EQUALLY SOLUBLE IN VINEGAR?

WILL OTHER SUBSTANCES DISSOLVE IN VINEGAR?

HOW CAN WE FIND OUT?

Give the children an opportunity to make suggestions. An obvious one is to try dissolving sugar, salt and some other substances with vinegar. Tell the children that that is what they are going to do -- experiment with vinegar as the solvent.

Children will be working in pairs to share the vinegar, so have each pair move their desks together. Have the children remove Worksheet 32 from their Student Manuals and get out their pencils. Assign monitors to distribute one reaction tray (containing the five substances) to each child. The children should put their trays in the appropriate place on the worksheet, as in the last lesson. Ask another child to give five toothpicks to each member of the class. Tell the class to use one toothpick for each substance. Show how you want the toothpicks placed when they are not being used for stirring (i.e. away from the bottom of the worksheet).



Worksheet 32
Unit 26

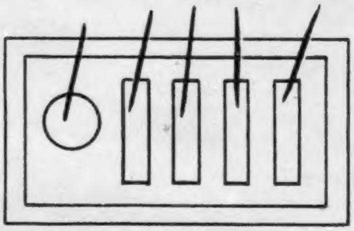
Name ____________________

Place your reaction tray here.

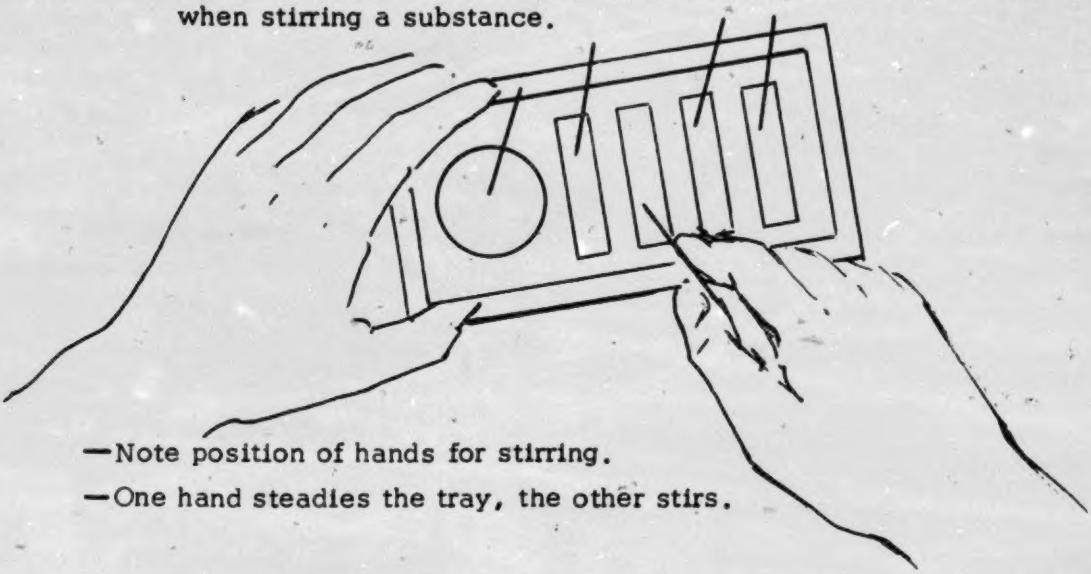
Dissolving in Vinegar

	Sugar (1 scoop)	Salt (1 scoop)	Soda (1 scoop)	Starch (1 scoop)	Detergent (1 scoop)
	Tally	Tally	Tally	Tally	Tally
Total number of drops to dissolve					
Other observations					

NOTE: See p.216 for possible results.



Placing the toothpicks in this position when not in use prevents the danger of knocking another toothpick from its well when stirring a substance.



—Note position of hands for stirring.

—One hand steadies the tray, the other stirs.

Again remind the children to be careful not to poke holes in the tray with the toothpicks.

Have a magnifier and a medicine dropper distributed to each child, and a container of vinegar to each pair of children. Explain that two children will share the vinegar and that they should remove their droppers each time they are used, so that the container will not tip over.

Have the children listen carefully as you give them the general instructions. You may want to list some of these on the chalkboard. When you have given the instructions, the children should be able to proceed on their own after Step 2, with only occasional guidance.

General Instructions:

Step 1 Add 5 drops of vinegar to all wells.

Tally the number of drops below each substance on the worksheet.

Stir each substance with its own toothpick.

Record any unusual observations at bottom of worksheet.

(NOTE: You may want the children to do Step 1 before you give them the other steps. They will probably observe that the soda bubbles.)

Step 2 Add 1 drop at a time to all wells.

Tally the number of drops.

Stir.

Make observations.

(NOTE: When and if any substance dissolves stop adding vinegar to that substance. Then record the total number of drops. Make observations for that substance.)

Step 3 After 10 drops have been added to any substance, add 5 drops at a time until the substance dissolves. If a substance has not dissolved by 75 drops, stop adding drops. Record observations for all substances (general appearance of each solution).

Have the children do the experiments in the prescribed manner. When they have finished, have them discuss the results. In this discussion the children should answer such questions as, "Did salt dissolve more easily in vinegar than sugar did? Or was sugar more soluble in it? Were both about equally soluble? What were the results when vinegar was added to the soda? To the starch? To the detergent?"

Possible results are :

	Sugar	Salt	Soda	Starch	Detergent
	5 I	5 𝍸 5 5 5 5 5 5 5 5 5 5 5 5 5	5 𝍸 5 5 5 5 5 5 5 }?	5 𝍸 5 5 5 5 5 5 5 5 5 5 5 5 5	5 𝍸 5 5 5 5 5 5 5 5 5 5 5 5 5
Total number of drops to dissolve	6	75	40-45	75	75
Other observations	dissolved at 6 drops.	almost clear, just a few tiny particles left. -looks cloudy	bubbles! -dissolved at 40-45 drops	- not dissolved -looks milky -very cloudy	- not dissolved. -few lumps. -foamy at edges

Ask the children why the soda bubbled and the other substances did not. Explain that bubble-formation is a property that appears when soda and vinegar are mixed. This kind of property is called a chemical reaction. Ask the children how this property of chemical reaction could be used to help identify materials. (If the children had an unknown white substance and it bubbled when mixed with vinegar, they could hypothesize that it might be soda.) Tell the children that in the next lesson they will do some experiments to test for the property of chemical reaction.

When cleaning up, set aside all the containers of vinegar and a medicine dropper for each, to use in Lesson 20. Have a team of children wash and rinse the rest of the droppers, and throw away the reaction trays and toothpicks.

NOTE: You will probably want to conduct both activities of the next lesson on the same day, while certain equipment is fresh and handy. For Activity B the children should bring in small samples of materials for testing. Do not reveal at this time what property is going to be tested. (The children will find out in Activity A that the property is a reaction of starch to iodine, and in Activity B they will be testing for the presence of starch in the materials.) You will want the children to bring both starchy and non-starchy materials, so choose a random assortment like the following:

any raw vegetable

small piece of wood

any raw fruit

stone

leaf

bits of cereal

piece of bread, cookie or other bakery product

newspaper, piece of stationery

dry beans or peas

plastic

flower petals

flour

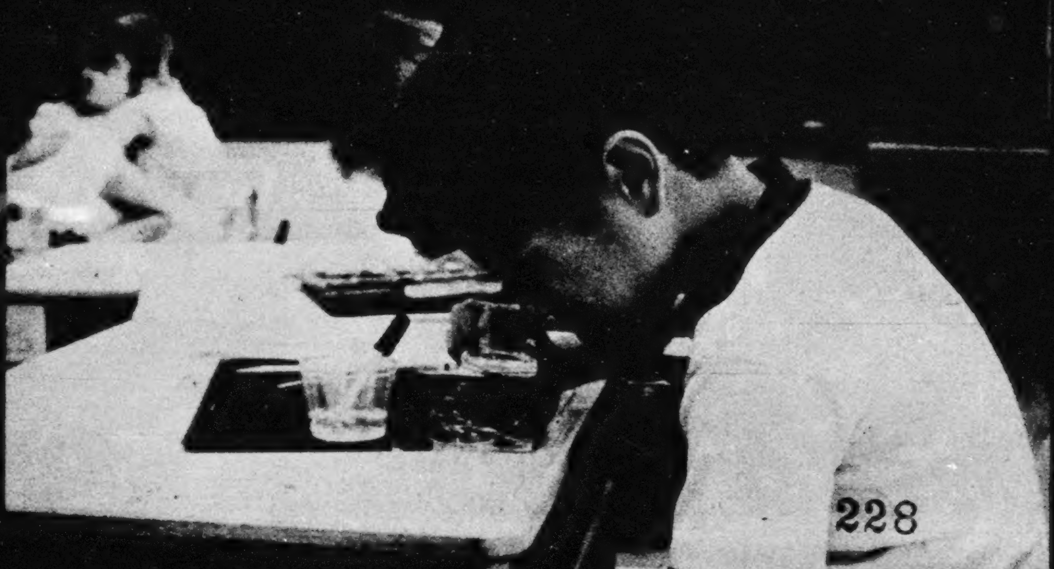
After instructing the children to bring in one or more small samples of the above, you may wish to say:

> IN THE NEXT LESSON WE ARE GOING TO LEARN A TEST TO TRY TO DISCOVER A NEW PROPERTY. AFTER WE LEARN HOW TO DO THAT, WE WILL NEED SOME EXTRA MATERIALS LIKE THOSE I JUST MENTIONED FOR EXPERIMENTS USING THE NEW TEST.

(To be sure the children get some noticeable results, be sure to have a raw potato and a banana on hand. These can be cut up later for use by the entire class.)

SECTION 8

CHEMICAL REACTION



SECTION 8 THE PROPERTY OF CHEMICAL REACTION

This section concludes the work of the unit. It consists of two lessons. In Lesson 19 the children perform experiments in which they use phenolphthalein (fee-nol-THAL-een) and iodine solutions, instead of the water and vinegar used in the solubility lessons. The purpose here is not to discover the solubility of various substances, but to discover a new property -- some reaction between a liquid and a powder -- that will enable the children to distinguish one substance from others. Eight white substances are tested with the solutions in Activity A, and the observations recorded. After discovering the reaction between starch and iodine in Activity A, the children test other materials for the presence of starch, in Activity B. (They use the materials brought from home for this.)

In Lesson 20, the children use all the data they have gathered in Sections 6 and 7 and in Lesson 19, and all the skills and learning acquired throughout the unit. It is an extremely important lesson, both to you and to them. It is important to you because it gives you help in evaluating the children's understanding of the purposes of the unit. Lesson 20 is important to the children, because -- in being given the opportunity here to use what they have learned to identify a number of unknown substances -- they will see that:

1. Each material has properties that distinguish it from other materials.

2. If you know the distinguishing properties, you can identify the materials. The more distinctive properties you can discover, the better your identification is.

3. To discover the properties of a material, you have to know tests that reveal the properties. The more tests you can give a material, the more properties you can discover and use as guides to better identifications.

Since the above are main purposes of the unit, do not let the seemingly long preparation for Lesson 20 deter you from teaching it. Upon looking it over, you will find that you have already prepared and used a good many of the materials in previous lessons, and are quite familiar with most of them.

Lesson 19: THE PROPERTY OF CHEMICAL REACTION

In Activity A of this lesson the children continue to explore the property of chemical reaction that was introduced in Lesson 18 when the class noticed bubbles resulting from the mixing of baking soda and vinegar. Here the children experiment with two different liquids and eight white substances. They make several discoveries, each of which is a change in the property of color. Of the color changes, the one most useful to the children for further experiments is the starch and iodine result. The children are told that scientists often use iodine to detect the presence of starch in a material. They know starch is present if iodine changes the color of a material to dark blue or purple.

In Activity B the children put this new knowledge to use to test various materials brought from home, as requested at the end of the last lesson. If they have not brought the materials, suggest that they do so tomorrow and schedule the activity for then. If they have brought the materials, you may wish to conduct both activities on the same day, while the children still have the iodine solutions and medicine droppers at hand. There is another reason for conducting both activities on the same day -- iodine solution, even though covered, loses its usefulness for testing in a few days.

It is not necessary to use the term "chemical reaction" in this lesson and the next, unless you wish to do so. "Reaction" is sufficient for the purposes.

MATERIALS

-- Activity A --

From the OMSI Kit:

- 4 one-ounce bottles of phenolphthalein solution
- 1 one-ounce bottle of iodine solution
- 30 one-ounce plastic containers

- 30 white plastic covers (Remove these from clear plastic vials that measure 3¼ inches in length and 1½ inches in diameter. These covers also fit the 1-ounce containers.)
- 30 medicine droppers
- roll of plastic wrap
- measuring cup

Also necessary:

- 1 cup of water
- marking pen
- 8 different white substances in 4-ounce containers, with scoops (from previous lessons)
- Worksheets 33 and 34

-- Activity B --

- raw potato
- banana
- samples of material brought by the children for testing (vegetables, other foods, wood, etc., as suggested at end of Lesson 13)
- 1 knife
- 15 containers of iodine solution with droppers
- paper, pencil
- newspaper to protect desks

PREPARATION

The materials for this lesson are based on a class of thirty. Each child works independently, but each pair of children must share a container of phenolphthalein solution and a container of iodine solution.

To make the iodine solution, pour one-half ounce of iodine (half the bottle) into one cup of water. Mix, then pour about one-half ounce into 15 one-ounce containers. Put a white plastic cover on each container, mark it "Iodine" and place on a tray. Place 15 medicine droppers on this tray also.

The phenolphthalein is already in a highly dilute solution, so it is necessary only to pour one-fourth bottle into the other 15 one-ounce containers. Cover and label these "Pheno" and place on a tray, along with 15 medicine droppers.

Also have ready, for distribution by monitors, 4-ounce containers of the 8 different white substances you prepared at the beginning of Section 6. Check to see that each substance still has a scoop in it.

PROCEDURE

Activity A

Briefly review the findings of the previous lesson. Remind the children that vinegar was mixed with five different substances, but reacted with only one. Ask which substance reacted, and how it reacted. (The soda reacted to the vinegar by bubbling.) Then ask:

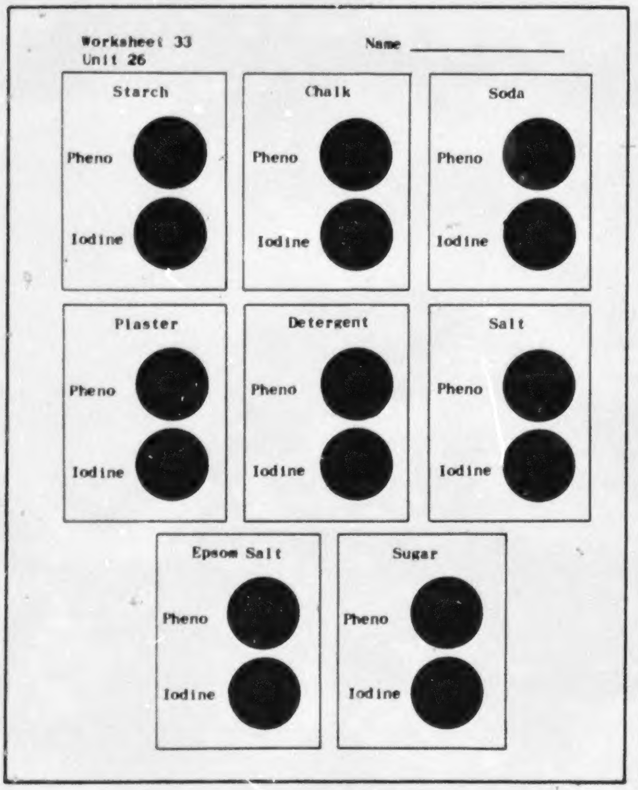
> COULD THIS PROPERTY OF REACTION BE USEFUL IN HELPING TO DISTINGUISH SODA FROM OTHER SUBSTANCES? (Yes.) HOW? (You could mix vinegar with each of the substances. If bubbles formed in a substance, you could hypothesize that it might be soda.)

Reiterate for the children that in the case of mixing vinegar and soda, "the property of reaction is useful in identifying a particular material." Then ask if the children think there might be other reactions, besides the property of bubbling, that might occur if other liquids than vinegar were used on the white substances. Let them think about this a little, then ask:

> WOULD YOU LIKE TO DO SOME EXPERIMENTS AND SEE WHETHER OR NOT YOU COULD DISCOVER OTHER REACTION PROPERTIES?

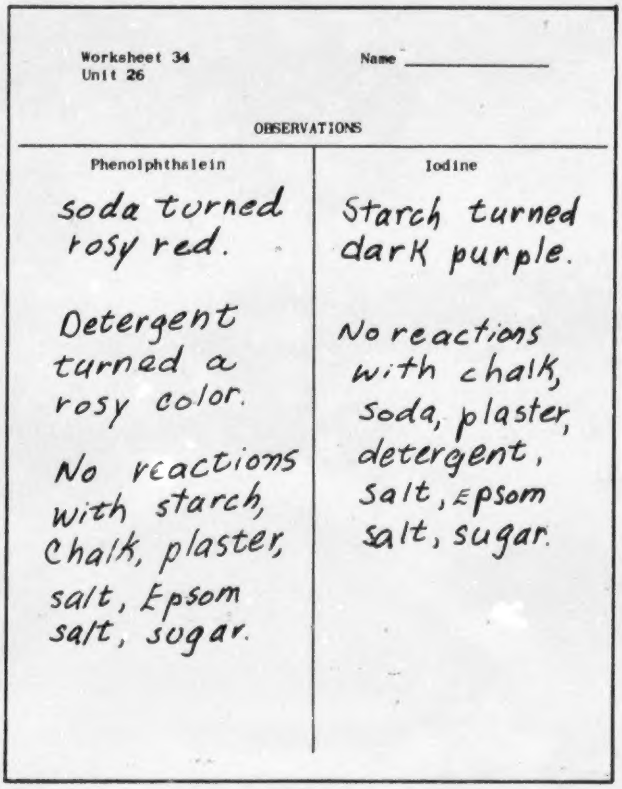
Show a container of phenolphthalein solution and a container of iodine solution. Ask the children to try to think of a way to use these two solutions to help discover possible reactions. The most common suggestion will probably be to mix each of the solutions with the white substances from the last lesson, and see what happens. If a reaction occurs, it could be recorded. The new reactions, if any, could be used to help distinguish one substance from another.

Explain that each child is going to have the opportunity to discover new properties of reaction for himself, after hearing the procedure and receiving materials. Say that each pair of children will have to share one phenolphthalein container and one iodine container, and should now arrange their desks accordingly. If the desks slant, ask the children to prop the tops up so that they are flat. When the desks are in place, and each child has a flat surface on which to work, have them remove Worksheets 33 and 34 from their Student Manuals. Each child will also need a pencil.



Worksheet 33
Unit 26
Name ______________

Starch: Pheno ● Iodine ●
Chalk: Pheno ● Iodine ●
Soda: Pheno ● Iodine ●
Plaster: Pheno ● Iodine ●
Detergent: Pheno ● Iodine ●
Salt: Pheno ● Iodine ●
Epsom Salt: Pheno ● Iodine ●
Sugar: Pheno ● Iodine ●



Worksheet 34
Unit 26
Name ______________

OBSERVATIONS

Phenolphthalein	Iodine
soda turned rosy red. Detergent turned a rosy color. No reactions with starch, Chalk, plaster, salt, Epsom salt, sugar.	Starch turned dark purple. No reactions with chalk, soda, plaster, detergent, Salt, Epsom salt, sugar.

Go through the following experimental procedure with the children:

Step 1. I will come to your desk and tear off a piece of plastic wrap that will fit over Worksheet 33. Each of you should place the plastic over Worksheet 33. The experiments will be done on the plastic. As I am doing this, I will explain how to use the rectangles on the worksheet.

Step 2. Each rectangle bears the name of a different substance. In each rectangle there are two black circles. Monitors will bring each of you two scoops of each of the eight different substances named on the worksheet. For example, you will get two scoops of starch. One scoop will be put on one black circle of the starch rectangle and the other scoop of starch will be placed on the other black circle in the same rectangle.

Step 3. When every child has two scoops of each substance, monitors will bring each pair of children a container of phenolphthalein solution and a container of iodine solution. They will also bring a medicine dropper for each solution. These medicine droppers are not to be contaminated by switching from one solution to the other. And they are not to be left in the containers because they will tip them over. Great care should be taken in removing the covers from the solutions, as the covers fit very tightly. Therefore, grasp the container and hold it firmly in place with one hand, while uncovering it with the other, so that the solution will not be spilled. Each child should start testing with only one solution. When he is done with that, he will exchange the solution and the dropper for his partner's. Each child is to put only 3 drops of a solution on the substance in the appropriate black circle. He should do one experiment at a time, observing carefully. Observations should be written on Worksheet 34.

Step 4. When partners have finished all the experiments, they should compare their results.

Assign two children to distribute each white substance with a scoop. (One child should serve one-half of the class, etc.) These children need not be too particular about the amount in each scoopful, but they should see that each student gets enough for his experiments. Ask all the students to cooperate in watching that the proper substance is put in the appropriate rectangle. Ask the distributors to be sure, too, that they are putting the material on the black circles in the correct rectangles. Do not let all the monitors start distributing materials at the same time. Let the first two get a head start, then send the next two with a second substance, etc.

Assign another child to distribute the 15 containers of phenolphthalein and 15 medicine droppers, one of each to each pair of children. Have a different child distribute the iodine solution and droppers in the same manner.

Ask everyone to be careful not to spill things. If a child's experiment sheet is somehow spoiled, provide fresh plastic and other materials.

When all of the children have their materials, remind them again to use only three drops of a solution on any substance. No more is needed, and besides they will be using what is left for future experiments. At this time warn them not to taste any of the experimental substances or solutions, and remind them not to contaminate the droppers. Then have them do the experiments.

When everyone has finished experimenting and writing observations, have a child collect the 15 containers of phenolphthalein and the 15 droppers that were used with this solution. Each container should be covered, placed on a tray and set aside for use in Lesson 20.

If you plan to conduct Activity B immediately, leave the iodine solution and droppers with the children. Otherwise have the iodine and droppers collected on a tray, covered, and saved for Activity B and Lesson 20.

Hold a class discussion of the results of the experiments. The children should have observed the following reactions:

1. The property of color change when phenolphthalein solution is added to soda. The mixture has a rosy color.

2. The property of color change when phenolphthalein solution is added to detergent powder. This mixture has a rosy color, too.

3. The property of color change when iodine solution is added to starch. The mixture has a dark blue or purple color -- almost black.

Discuss the implications of these reactions as tests to help distinguish one substance from another. Tell the children that scientists often use iodine on materials to find out whether they contain starch. The property of reaction to iodine -- the change to a very dark blue or purple color -- is the clue that starch is present.

Tell the children that in the next activity they will have a chance to test whatever materials they have brought for the presence of starch.

Conclude the activity by asking each child to pick up his plastic sheet carefully, corner by corner, and throw it in the waste basket. Save Worksheet 34 for use in Lesson 20.

Activity B

Have the children work in pairs or in larger groups, depending on the number of materials they brought for testing. Let them have a little fun conjecturing about what they will find. Will a rock (flower petal, bean, piece of wood, etc.) contain starch? How about the newspaper, or a carrot? Then have them put each material on newspaper and then one drop of iodine solution on the material to test it for the presence of starch. Assign some children to test various kinds of paper, including newspaper, a page in a Student Manual, good note paper, etc. Cut up a potato and a banana, distribute the pieces and have the children test these, too.

When all the materials have been tested, hold a class discussion of the results. You might like to list on the chalkboard all those items that showed the starch reaction and all those that did not. The children could copy these to take home and discuss further.

Results of the paper tests should be interesting to the children. There will be no color change on newspaper (and maybe not on note paper), but there will be a change in the paper in the Student Manual after a few seconds.

Some vegetables (such as peas, beans and carrots and especially the raw potatoes) and some fruits (such as bananas) will show the property of reaction. So, generally, will breads, cookies, cakes, cereals and flour samples.

Lesson 20: IDENTIFYING UNKNOWNS BY THEIR PROPERTIES

Each of the three activities of this lesson is quite different from the others, but all are extremely valuable to the child in showing him the usefulness of the unit concepts and skills.

In Activity A the children use a large foldout chart (Worksheet 35) on which some information about their experimental substances is already provided. They fill in the remaining blanks on this chart with data from Lessons 17, 18 and 19 (Worksheets 31, 32 and 34). They now have information about the shape, solubility and reaction properties of eight different white substances.

In Activity B each child receives an unknown substance and is challenged to identify it by testing its properties in several ways. First he examines the material with a magnifier to see if the particles have a distinctive crystal shape. Then he tests its solubility in both water and vinegar. Next he tests for a reaction property, using phenolphthalein and iodine solutions. He keeps a record of his findings on Worksheet 36.

As the children are doing their experiments in Activity B they check with the chart on Worksheet 35 to see if their substances have properties similar to any of the substances described on the chart. By the conclusion of their tests, most of the children will be able to identify their substances. However, the two children who work with the surprise item (fine white sand) will be very curious about what they have. There is no picture of sand on the chart (though it may look very much like sugar under a magnifier), it is not soluble, and it does not react to the chemicals. You can use this information to point out to the children that it is also useful to know what something is not. In this case, the children know that the sand is not any of the eight other white substances. This narrows down an experimenter's hypotheses and suggests that he must find others.

In Activity C the children discuss the findings of Activity B. Differences in results can be resolved by consulting the chart (Worksheet 35), and by your code letter label. The children who received sand are told what their substance is and the class fills in the information in the empty row at the bottom of the chart. The discussion should focus on the importance of knowing many properties of a material when trying to identify it, and on how to discover the properties (by tests).

Conclude the unit by having the children review all the properties they studied and by having them describe the various tests they used. Encourage them to take their worksheets home to summarize for their families what they have learned in this unit.

MATERIALS

-- Activity A (for each child) --

- Worksheets 31, 32 and 34 from previous lessons, and Worksheet 35
- pencil

-- Activity B (for each child) --

- Worksheets 35 and 36
- pencil
- reaction tray
- 2 toothpicks
- 1 four-ounce container of unknown white substance, with scoop
- magnifier

-- Activity B (for each pair) --

- 4 liquids in containers on styrofoam tray, each with its own dropper, as follows:
  4-ounce container of water
  4-ounce container of vinegar (from Lesson 18)

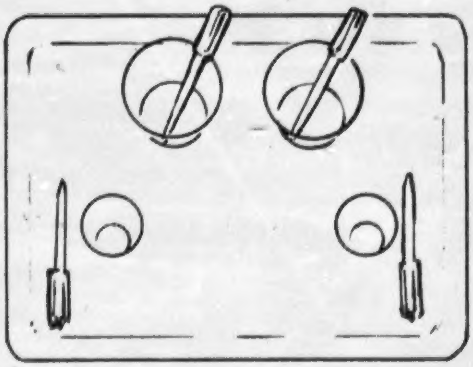
1-ounce container of phenolphthalein solution (from Lesson 19)
1-ounce container of iodine solution (from Lesson 19)

-- Activity C --

- Worksheets 35 and 36
- pencil

PREPARATION

The materials for this lesson are based on a class of 30 children. Each child is given a reaction tray and an unknown substance to test in it. Each pair of children must share a tray of the liquids. From the OMSI kit, get 15 styrofoam trays and put four containers of liquids on each tray, with droppers. In order to keep the droppers free from contamination, the following arrangement of the droppers and liquids on the tray is suggested:



You will need nearly all the 4-ounce containers of white substances that you prepared with scoops at the beginning of Section 6, plus two new containers of white sand. All identification must now be removed from these and each substance code-labeled with a letter of the alphabet. With a marking pen, code-label as follows:

A - plaster
B - salt
C - soda
D - chalk
E - sugar
F - starch
G - dry detergent
H - Epsom salt
I - sand

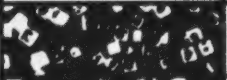
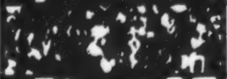
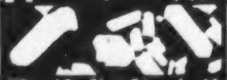
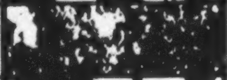
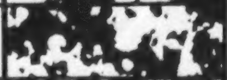
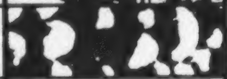
PROCEDURE

Activity A

See that each child has his data from Lessons 17, 18 and 19 (Worksheets 31, 32 and 34). Ask the children to open their manuals to Worksheet 35, which is a foldout sheet. Discuss the chart on the foldout worksheet. Tell the children that pictures and some data have been provided, but that they should complete the chart by filling in the data they collected on Worksheets 31, 32 and 34. Circulate among them, checking their work.

Worksheet 35
Unit 26

The letter of my substance is ____________________ Name ________________

NAME OF WHITE SUBSTANCE	SHAPE OF SOLID	SOLUBILITY		REACTION	
		Water (75 drop limit)	Vinegar (75 drop limit)	Phenolphthalein (3 drops)	Iodine (3 drops)
SALT		at 75 drops - almost dissolved - a little cloudy - a few tiny particles floating around	at 75 drops - almost dissolved - a little cloudy - a few tiny particles floating around.	no reaction	no reaction
SUGAR		5 to 7 drops - dissolves.	5 to 7 drops - dissolves.	no reaction	no reaction
EPSOM SALT		8 to 12 drops - dissolves.	8 to 12 drops - dissolves.	no reaction	no reaction
SODA		45 to 50 drops - dissolves.	BUBBLES - FIZZES 40 to 45 drops dissolves. (a few bubbles on bottom of tray).	- turns pink or rose color.	no reaction
STARCH		at 75 drops - milky looking cloudy	at 75 drops - milky looking cloudy	no reaction	- turns deep blue or purple - almost black
CHALK		at 75 drops - milky looking cloudy	BUBBLES - FIZZES 70 to 75 drops dissolves.	no reaction	no reaction
PLASTER		at 75 drops - milky looking cloudy	at 75 drops - milky looking cloudy	no reaction	no reaction
DETERGENT		at 75 drops - a little cloudy - several chunks floating around	at 75 drops - cloudy - foamy around edges - several chunks floating around	- turns rose colored or bright red	no reaction

When everyone has transferred his data to the chart, discuss how the chart could be used.

> IF I GAVE EACH OF YOU AN UNKNOWN WHITE SUBSTANCE, AND YOU TESTED IT WITH THE TESTS LISTED AT THE TOP OF THE CHART, HOW COULD THIS CHART BE USEFUL?

The children should see that if they examined an unknown white substance for shape, for solubility, and for reaction properties, they could check their results with the chart to help identify the unknown material.

> IN THE NEXT ACTIVITY I AM GOING TO GIVE EACH OF YOU AN UNKNOWN WHITE SUBSTANCE. YOU WILL LOOK AT THE SHAPE OF ITS PARTICLES THROUGH A MAGNIFIER, THEN TEST IT FOR SOLUBILITY WITH WATER AND WITH VINEGAR. FINALLY YOU WILL TEST FOR THE PROPERTY OF REACTION WITH PHENOLPHTHALEIN AND IODINE SOLUTIONS. WHEN YOU HAVE DONE EACH TEST, THIS CHART SHOULD HELP YOU EITHER TO IDENTIFY YOUR SUBSTANCE OR TO TELL WHAT IT IS NOT.

Activity B: Testing

Remind the children that in this activity each child is going to receive an unknown white substance to try to identify by tests. Explain that each pair of children will be sharing the test liquids. Have each pair push their desks together. Now ask each child to remove Worksheets 35 and 36 from their Student Manuals, put away the manuals and take out a pencil. If desks are slanted, have the tops propped up so that each child has a flat surface on which to work.

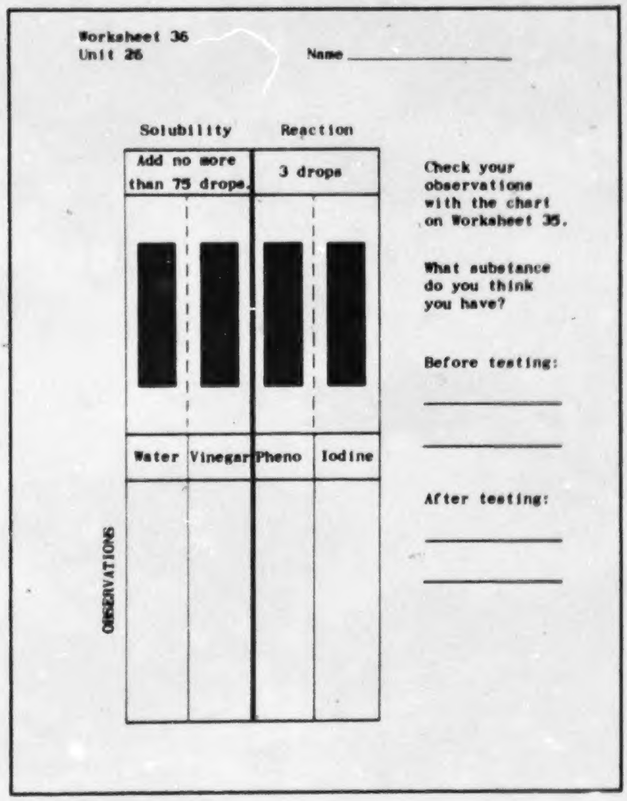
Describe the experimental procedure the children will use:

Step 1. Monitors will bring to each pair:

- a tray with 4 containers of liquids, each with its own dropper
- 2 magnifiers
- 2 reaction trays
- 4 toothpicks
- 2 containers of unknown white substances (Both children will not necessarily get the same kind of substance.)

From these items, each child should take two toothpicks and one of each of the other materials. (They will share the liquids.) Then the children should write the code letter of their unknown substance at the top of Worksheet 35 (chart).

Step 2. Each child should put his reaction tray on the appropriate place on Worksheet 36. The round well will not be used -- it should be placed so that it is on the left of the worksheet and then be ignored.



Worksheet 36
Unit 26

Name ____________

Solubility		Reaction	
Add no more than 75 drops.		3 drops	
Water	Vinegar	Pheno	Iodine

OBSERVATIONS

Check your observations with the chart on Worksheet 35.

What substance do you think you have?

Before testing:

____

____

After testing:

____

____

Step 3. Each child should put 1 scoop of his substance in each of the 4 rectangular wells in his reaction tray.

Step 4. The magnifier should be used to examine the substance. Then the pictures of substances on Worksheet 35 should be examined to see if any resemble the unknown substance. (Discuss an example.)

Step 5. The children should try to dissolve their substances with water and then with vinegar. They should use the same procedures they used in previous solubility lessons. That is, they should add 5 drops of the liquid and stir -- then add 1 drop at a time until they get to 10 drops and stir again. After 10 drops they should add 5 at a time. They should keep a tally of the drops used in each case.

STOP ADDING DROPS AT ANY TIME THAT YOU THINK A SUBSTANCE IS DISSOLVED -- WHEN NO PARTICLES CAN BE SEEN IN THE SOLUTION. EVERYONE SHOULD STOP AT 75 DROPS WHETHER THE SUBSTANCE HAS DISSOLVED OR NOT.

When a substance has been dissolved, or when 75 drops have been added to it, the children should stop and record their observations on Worksheet 36 in the appropriate place. Then they should check to see if their observations match any on Worksheet 35 (the chart). (Discuss an example.)

Step 6. When the children have tried the solubility tests, they should try the reaction tests with 3 drops of phenolphthalein solution and 3 drops of iodine solution. Observations should be written in the proper columns of Worksheet 36. Again the children should check all the information in the reaction columns of Worksheet 35 to see if any correspond with their own observations. (Discuss an example.)

Step 7. If a child checks all the rectangles for a given substance on Worksheet 35 (chart), he can then hypothesize that he has that substance.

Step 8. When you think the children understand what they are to do, let them go to it!

If a child wants to hypothesize about the identity of his material after just one or two tests (or after just checking its shape), say, "You may be right, but you need more evidence to make a good hypothesis. You should do all the tests to get the best possible identification."

When the tests are finished and the observations are all recorded on Worksheet 36, ask each child if he identified his substance as one of those described on Worksheet 35. (Most will have done so.) Tell the children to save both worksheets to discuss in the next activity.

Activity C: Discussion and Review

Ask all the children who worked with Substance A to give their results from Worksheet 36. Ask what substance they think they have and why they think so. If there are discrepancies in their test results, have the children resolve these by checking for possible errors they may have made in testing or measuring or tallying. Write on the chalkboard the code letter "A" and the identification the children agree upon.

Do this for each substance. The findings of the children who worked with Substance I (the sand) should be quite puzzling to them. Under the magnifier the material may have looked much like sugar, but it did not dissolve and it did not react to either the phenolphthalein or the iodine solutions. Let the children hypothesize about what this substance could possibly be. They may say that Substance I does not fit any of the descriptions of the eight substances on Worksheet 35 and so probably is not any of these. (Some child may even hazard a guess that the substance is sand.) Accept all hypotheses, then list the code letters and correct names on the chalkboard so that everyone can see if he has identified his substance properly. Point out the importance of the work with sand by asking:

> IS IT HELPFUL TO KNOW THAT SUBSTANCE I IS NOT ANY OF THE EIGHT SUBSTANCES LISTED ON WORKSHEET 35? (Yes. It narrows down the field of investigation.)
>
> WHAT WOULD WE HAVE HAD TO DO IF I HAD NOT TOLD YOU THAT SUBSTANCE I IS SAND? (We would have had to make new hypotheses and learn new methods of testing for other properties.)

Tell the children that there are tests for discovering whether or not a substance is sand (it melts at very high temperatures, for example), but the necessary equipment would not be available to a regular classroom. Have the children write "Sand" and the test results for it in the empty row at the bottom of Worksheet 35. (Encourage them to take their completed worksheets home later to show to and discuss with their families.)

Conclude by having the children review each property they studied in this unit (hardness, density, etc.). Ask them to recall how they tested for each property. Emphasize the three ideas given in the Section 8 Commentary, namely:

1. Each material has properties that distinguish it from other materials.

2. If you know the distinguishing properties, you can identify the materials. The more distinctive properties you can discover, the better your identification is.

3. To discover the properties of a material, you have to know tests that reveal the properties. The more tests you can give a material, the more properties you can discover and use as guides to better identifications.

The front and back covers of this book are photographs taken by Sonia Forseth. They show eight white substances studied in this unit. The substances are table salt, cornstarch, Epsom salt, sugar, dry detergent, baking soda, powdered chalk and plaster.

Other highly magnified pictures of these substances on Worksheets 21, 22 and 35 were taken especially for this unit by:

Warner Clapp
Senior Photographer
Audio Visual Resources
University of Minnesota